COSEWIC
Assessment and Status Report

on the

Vancouver Island Marmot
Marmota vancouverensis

in Canada

ENDANGERED
2019

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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COSEWIC. 2008. COSEWIC assessment and update status report on the Vancouver Island marmot *Marmota vancouverensis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 29 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

COSEWIC. 2000. COSEWIC assessment and update status report on the Vancouver Island marmot *Marmota vancouverensis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 29 pp.

Bryant, A.A. 1997. Update COSEWIC status report on the Vancouver Island marmot *Marmota vancouverensis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-25 pp.

Munro, W.T. 1978. COSEWIC status report on the Vancouver Island marmot *Marmota vancouverensis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 12 pp.

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For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment and Climate Change Canada
Ottawa, ON
K1A 0H3

Tel.: 819-938-4125
Fax: 819-938-3984
E-mail: ec.cosepac-cosewic.ec@canada.ca
https://www.canada.ca/en/environment-climate-change/services/committee-status-endangered-wildlife.html

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COSEWIC
Assessment Summary

Assessment Summary – May 2019

Common name
Vancouver Island Marmot

Scientific name
Marmota vancouverensis

Status
Endangered

Reason for designation
This endemic species is found only on Vancouver Island, British Columbia. Since the last assessment in 2008, the species has demonstrated a rapid population increase and then a subsequent decline; there are currently an estimated 88–101 mature animals in the wild. Ongoing predation remains high and there are potential threats from inbreeding and climate change. A successful captive-breeding program and resulting population supplementation has been reduced. A population viability analysis suggests that there is a high probability of extinction if there are extended periods of low adult survival, as observed during previous and most recent declines, and there are relatively few captive-bred animals introduced into the extant wild colonies.

Occurrence
British Columbia

Status history
Designated Endangered in April 1978. Status re-examined and confirmed Endangered in April 1997, May 2000, April 2008, and May 2019.

COSEWIC
Executive Summary

Vancouver Island Marmot
Marmota vancouverensis

Vancouver Island Marmot (*Marmota vancouverensis*) is a colonial marmot that is closely related to Hoary Marmot (*M. caligata*) and Olympic Marmot (*M. olympus*). It is notable for its chocolate brown fur, unique vocalizations, atypical skull characteristics, and highly social nature. It is one of only five endemic species of mammal in Canada.

Distribution

Vancouver Island Marmot is endemic to Vancouver Island, British Columbia, Canada. Its current known distribution is limited to 25 mountains in four locations on Vancouver Island: 14 mountains in Nanaimo Lakes, nine mountains in Strathcona, and one mountain in each of Schoen Lake and Clayoquot Plateau. Vancouver Island Marmot is also held at the Calgary Zoo, the Toronto Zoo, and the Tony Barrett Mount Washington Marmot Recovery Centre for captive-breeding purposes.

Habitat

The natural habitat of Vancouver Island Marmot consists of subalpine meadows, usually at 900–1500 m above sea level. These natural meadows are created and maintained by avalanches, slower downhill movement of snow (i.e., snow-creep), fire, or a combination of processes. Patches of natural habitat on Vancouver Island tend to be both smaller and located farther apart than those occupied by other marmot species on the nearby mainland and Olympic Peninsula. Vancouver Island Marmot also uses forested areas as low as 700 m above sea level where clearings that mimic natural meadows are created by anthropogenic activities such as logging, mining developments, and ski facilities. Of these, only active ski runs provide habitat that supports colonies long term. Colonies in logging cut-blocks have become locally extirpated within 5–19 years; these anthropogenic habitats function as an ecological trap.

Biology

Vancouver Island Marmot is a fossorial herbivore that hibernates from early October through late April. Most females are reproductively mature at age two, but most do not breed until age three or four, producing litters of 1–7 pups every second year on average. Both sexes disperse, usually < 10 km straight-line distance, typically at age two. The maximum observed age is 12 years in the wild and 14 years in captivity.

Population Sizes and Trends

Annual population surveys since 1979 indicate that marmot numbers at least doubled during the 1980s, with most of this increase occurring in new habitats created by logging of old-growth forests. A minimum of 235 marmots was counted in 1984, but it is likely that the population numbered 300–350 at this time, with most of the population in meadow-like habitats created by human activities. The population declined precipitously during the 1990s, with only ~70 individuals remaining in the wild by 1997. The proximate cause of the decline was increased predation. In 2007 there were about 50 wild-born marmots in the wild.

The marmot population grew considerably between 2007 and 2012/2013, at which time the population in the wild was estimated to be approximately 300 marmots distributed among at least 25 different mountains. Population growth was the result of both reproduction in the wild and the release of captive-born marmots; a captive-breeding population was established in 1997. Between 2013 and 2017, however, the wild population declined every year, with annual rates of decline of 3–30%. This rate includes the recruitment of captive-released marmots into the wild population, so the rate of decline based on reproduction and survival of marmots in the wild population was even greater. The reason for the decline varied among years. Initially there was poor reproduction, which coincided with very dry summers, and there was low overwinter survival at one location following a dry summer. More recently, there was high mortality due to Cougar (*Puma concolor*) predation at another location. The most recent decline (2013–2017) also corresponded with a reduction in the number of captive-born marmots that were released into the wild.

In 2017, there were an estimated 135 (min. = 127, max. = 142) Vancouver Island Marmot in the wild. Ninety-one (min. = 86, max. = 95) were mature individuals (≥ 2 years old), and 38 (min. = 37, max. = 39) were pups. The count included both wild-born marmots and captive-born marmots that survived at least one hibernation after being released to the wild; 11 captive yearlings released in 2017 were excluded from the count. Additionally, there were 49 marmots in captivity, slightly fewer than half of which (22) were mature individuals.

Threats and Limiting Factors

The primary immediate threat to Vancouver Island Marmot is predation, largely by Cougar, Grey Wolf (*Canis lupus*), and Golden Eagle (*Aquila chrysaetos*). If these predators are drawn to high elevation by their primary prey, Columbian Black-tailed Deer (*Odocoileus hemionus columbianus*) and Roosevelt Elk (*Cervus elaphus roosevelti*), they will opportunistically prey upon marmots. Elk and deer will forage on early successional vegetation in cut-blocks; thus, ecosystem changes following logging at high elevation pose another threat to Vancouver Island Marmot. A long-term threat to Vancouver Island Marmot is loss of habitat from climate change. Under a “worst case” scenario, up to 97% of the suitable marmot habitat on Vancouver Island may disappear by 2080.

Like other alpine-dwelling marmot species, Vancouver Island Marmot is limited by low reproductive output. Furthermore, the small size of the current wild population makes the population more susceptible to disease and stochastic demographic or weather events. There is evidence that Vancouver Island Marmot is limited at low population density by Allee effects. Additional limitations include genetic isolation and a lack of suitable habitat within dispersal distance of active colonies.

Protection, Status and Ranks

Vancouver Island Marmot was assessed as Endangered by COSEWIC in April 1978, April 1997, May 2000, April 2008, and May 2019. It is listed as Endangered on Schedule 1 of Canada’s *Species at Risk Act* (SARA). The species was listed as Endangered under the B.C. *Wildlife Act* and under the U.S. *Endangered Species Act*. Vancouver Island Marmot was assessed as Endangered by the IUCN. Two protected areas have been established specifically to protect marmot habitat – the Haley Lake Ecological Reserve (888 ha) and the Green Mountain Wildlife Critical Habitat Area (300 ha). Marmots also live in Strathcona, Schoen Lake, and Clayoquot Plateau Provincial Parks, all of which are afforded habitat protection under the B.C. *Park Act*.

TECHNICAL SUMMARY

Marmota vancouverensis

Vancouver Island Marmot

Marmotte de l'île de Vancouver

Range of occurrence in Canada: British Columbia (Vancouver Island)

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines (2011) is being used)	5.28 years (SD = 1.65, n = 297)
Is there an observed, inferred, or projected continuing decline in number of mature individuals?	Yes, observed. -23% between 2010 and 2017
Estimated percent of continuing decline in total number of mature individuals within 5 years or 2 generations.	-68% in 2 generations (10 years) based on λ = 0.88; assumes continued augmentation of population with captive-born marmots at current levels and average λ during most recent decline in adult numbers (2013–2017)
Observed, estimated, inferred, or suspected percent reduction or increase in total number of mature individuals over the last 10 years, or 3 generations.	Observed 3 generations: +288% or 284% assuming exponential and linear growth, respectively First 2 generations (2001–2012): +1332% or +731% assuming exponential and linear growth, respectively Most recent generation (2012–2017): -78% or -66% assuming exponential and linear growth, respectively
Projected or suspected percent reduction or increase in total number of mature individuals over the next 10 years, or 3 generations.	Possible reduction, but uncertain; annual λ has varied from 0.8–1.4 from 2010–2017
Observed, estimated, inferred, or suspected percent reduction or increase in total number of mature individuals over any 10 years, or 3 generations period, over a time period including both the past and the future.	Possible reduction, but uncertain; annual λ has varied from 0.8–1.4 from 2010–2017
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. No; possibly reversible short term through predator control b. Yes, partially c. No for proximate cause of decline, predation
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	5,653 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	248 km²
Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. No
Number of "locations" (use plausible range to reflect uncertainty if appropriate)	2–4
Is there an observed, inferred, or projected decline in extent of occurrence?	No
Is there an observed, inferred, or projected decline in index of area of occupancy?	None observed Projected decline if current population decline not reversed
Is there an observed, inferred, or projected decline in number of subpopulations?	None observed Projected decline if current population decline not reversed
Is there an observed, inferred, or projected decline in number of "locations"*?	None observed Projected decline if current population decline not reversed
Is there an observed, inferred, or projected decline in area, extent and/or quality of habitat?	SHORT TERM (3 generations) No – some minor decreases in quality on a local scale but not overall LONG TERM Yes – up to 97% loss of suitable habitat by 2080 under "worst case" climate change prediction
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of "locations"?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
Nanaimo Lakes	38–42
Strathcona	48–53
Clayoquot Plateau	2–4 (in 2016)
Schoen Lake	0–2 (in 2016)
Captive population	22
Total	88–101 in wild pop (includes captive-born marmots that have survived at least 1 hibernation in wild) 22 in captive pop

Quantitative Analysis

Is the probability of extinction in the wild at least 20% within 20 years or 5 generations, or 10% within 100 years?	For $PE_{20/5gen.}$: not calculated directly For PE_{100} (from Jackson *et al.* 2015) No: if populations have relatively high survival rates associated with observed growth of the population (PE_{100} <1% across K values 200–350) Yes: if populations have continuously low survival rates observed during previous declines (PE_{100} = 100% in absence of management)

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for this species? Yes (in Sept 2016 for the BC Ministry of Environment) Overall threat impact: Medium–High Predation by native predators, which in part is facilitated by anthropogenic habitat alteration: High–Low Ecosystem modification resulting from logging and wood harvesting: Medium Longer term – habitat contraction caused by climate change: High–Low What additional limiting factors are relevant? Naturally low reproductive rate Small population size that increases risk posed by stochastic events; evidence Vancouver Island Marmot may be susceptible to Allee effects Genetic isolation and inbreeding in the absence of active management

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	None – species is endemic
Is immigration known or possible?	Not applicable
Would immigrants be adapted to survive in Canada?	Not applicable

Is there sufficient habitat for immigrants in Canada?	Not applicable
Are conditions deteriorating in Canada?	Not applicable
Are conditions for the source (i.e., outside) population deteriorating?	Not applicable
Is the Canadian population considered to be a sink?	Not applicable
Is rescue from outside populations likely?	Not applicable

Data Sensitive Species

Is this a data sensitive species?	No

Status History

COSEWIC: Designated Endangered in April 1978. Status re-examined and confirmed Endangered in April 1997, May 2000, April 2008, and May 2019.

Status and Reasons for Designation:

Status: Endangered	**Alpha-numeric codes:** B2ab(v); C2a(i); D1; E
Reasons for designation: This endemic species is found only on Vancouver Island, British Columbia. Since the last assessment in 2008, the species has demonstrated a rapid population increase and then a subsequent decline; there are currently an estimated 88–101 mature animals in the wild. Ongoing predation remains high and there are potential threats from inbreeding and climate change. A successful captive-breeding program and resulting population supplementation has been reduced. A population viability analysis suggests that there is a high probability of extinction if there are extended periods of low adult survival, as observed during previous and most recent declines, and there are relatively few captive-bred animals introduced into the extant wild colonies.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. The recent decline was offset by a rapid increase in population growth over the first two generations.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered B2ab(v) as IAO (248 km^2) is less than 500 km^2, the population is restricted to fewer than five locations (a) and there is a continuing observed decline in the number of mature individuals (b(v)).
Criterion C (Small and Declining Number of Mature Individuals): Meets Endangered C2a(i) as there are fewer than 2500 mature individuals and a continuing decline with no population having more than 250 mature individuals.
Criterion D (Very Small or Restricted Population): Meets Endangered D1 as there are fewer than 250 mature individuals.
Criterion E (Quantitative Analysis): Meets Endangered E as a quantitative population viability analysis revealed a high probability of extinction over 5 generations (PE_{100}=100%) if the species has continuously low survival, as observed during previous and most recent declines, and there is no supplementation through captive breeding.

PREFACE

Since the 2008 assessment of Vancouver Island Marmot by COSEWIC, the population has undergone a significant increase in abundance followed by a more recent decline. From 2008 to 2012/2013, the number of marmots tripled due to reproduction in the wild and the release and recruitment of captive-born marmots into the wild population. The increase in population size was accompanied by an increase in the number of mountains with marmot colonies from ~ 15 in 2008 to at least 25 sites in 2017. The extent of occupancy quadrupled in area over that period. Since 2013, however, the total number of marmots has declined every year. The reason for the decline varied among years. Initially there was poor reproduction, which coincided with very dry summers, and there was also low overwinter survival at one colony following a dry summer. More recently (2017), there was high mortality due to Cougar predation at another location. The total population size in the wild in 2017 was about 1.5 times larger than it was when last assessed by COSEWIC, but it is only about half the size it was in 2012/2013. The most recent decrease in population size has not yet resulted in a substantial decrease in the number of sites or extent of occupancy.

Since the last assessment, 405 captive-born marmots have been released to the wild population; captive-born individuals released to augment wild populations have successfully weaned wild-born offspring and contributed to population growth. Despite the positive contribution and success of the captive-breeding program, the captive population was reduced from 177 marmots in 2008 to 49 in 2017, and the number of captive-breeding facilities has been reduced from four to three. The decision to downsize the captive population and breeding program was because of lack of secure funding.

In 2014, an IUCN sponsored workshop was held to conduct a population and habitat viability analysis. Results suggested that Vancouver Island Marmot had a high probability of persistence if survival rates were consistent with the observed growth of the population. However, the species will require active management to ensure gene flow between subpopulations that prevents inbreeding depression. The model predicted that high rates of predation, consistent with survival estimates observed during the most recent population decline, will cause the extinction of Vancouver Island Marmot, but this trajectory could be reversed by reducing predation or by augmenting the wild population with large numbers (> 60) of captive-born marmots annually.

As part of COSEWIC status assessments, Aboriginal Traditional Knowledge (ATK) reports are prepared by the Aboriginal Traditional Knowledge subcommittee (ATK SC). These reports compile and summarize ATK relevant to status assessment when ATK information is available and readily accessible. A gathering project may be conducted if there are information gaps, or if ambiguity exists between ATK and other forms of knowledge.

All species are significant and are interconnected and interrelated. Vancouver Island Marmot is culturally important to Indigenous people on Vancouver Island. Archaeological evidence of faunal remains indicates past use, although contemporary ATK was unavailable during the time the COSEWIC status report was in preparation.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2019)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as “Vulnerable” from 1990 to 1999, or “Rare” prior to 1990.

** Formerly described as “Not In Any Category”, or “No Designation Required.”

*** Formerly described as “Indeterminate” from 1994 to 1999 or “ISIBD” (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment and Climate Change Canada — Environnement et Changement climatique Canada
Canadian Wildlife Service — Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment and Climate Change Canada, provides full administrative and financial support to the COSEWIC Secretariat.

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Vancouver Island Marmot (*Marmota vancouverensis*: Swarth 1911) was originally described from specimens collected in 1910 (Swarth 1911, 1912) and is one of 15 extant species within the genus (Armitage 2014). *Marmota* is divided into two subgenera, each of which represents a monophyletic lineage. *M. vancouverensis* belongs to the subgenus *Petromarmota* which contains three additional species found in Western North America – Yellow-bellied Marmot (*M. flaviventris*), Hoary Marmot (*M. caligata*), and Olympic Marmot (*M. olympus*) (Armitage 2014).

Vancouver Island Marmot is more closely related to Hoary Marmot, found on the British Columbia mainland, than Olympic Marmot found on the nearby Olympic Peninsula of Washington State (Steppan *et al.* 2011, Kerhoulas *et al.* 2015 but see Kruckenhauser *et al.* 1999). Limited genetic differences among these three species suggest rapid, recent divergence within this clade (Kerhoulas *et al.* 2015). Based on the measured genetic distances among species, *M. olympus* diverged from the *M. caligata – M. vancouverensis* lineage ~ 2.6 MYA and *M. vancouverensis* diverged from *M. caligata* ~ 0.4–1.2 MYA (Steppan *et al.* 2011, Yan *et al.* 2017). Recent studies of mitochondrial and nuclear DNA suggest that since divergence, there may have been intermittent, and possibly ongoing, gene flow between *M. caligata* and both *M. vancouverensis* and *M. olympus* (Kerhoulas *et al.* 2015).

Morphological Description

Vancouver Island Marmot is notable among marmots for its unique dark chocolate fur colour and contrasting patches of white fur on the nose, belly and top of the head (Nagorsen 2005). New fur is particularly dark and almost black in young of the year. Older fur weathers to tan or cinnamon colour. Because marmots may not fully moult in a single year, older animals often display a variegated fur pattern (Heard 1977).

Compared to other species of marmots, Vancouver Island Marmot has atypical skull morphology (Cardini *et al.* 2005) and a unique vocalization (Heard 1977, Blumstein 1999). The atypical skull morphology is related to the maxillary, the squamosal process of the zygomatic arch, and the tympanic bullae. The unique call is a frequent, short (0.29 ± 0.02 second) “kee-aw” call not used by other species of marmot (Heard 1977). The call appears to function as a low-level alarm that is used to communicate uneasiness in response to a disturbance, such as after a predator has left the area.

Adults typically measure 67–72 cm from the nose to the tip of the tail (mean = 69.7 cm, SD = 4.0, n = 68; COSEWIC 2008). Vancouver Island Marmot reaches this adult body length at three years of age (McAdie 2015). Like other hibernating mammals, mass varies considerably depending upon time of year. Adult females may increase from 3.5 kg shortly after emergence in late April to 5–5.5 kg by the onset of hibernation in early October (Heard 1977) with the mass gain occurring in July and August (McAdie 2015). Mass gain is influenced by local conditions and reproductive status, but an average adult female gains 15–18 g per day (COSEWIC 2008). Males tend to be structurally larger (~ 106%) and heavier (~ 115%) than females (McAdie 2015) but gain mass at similar rates to females (COSEWIC 2008) over a longer period (July to September; McAdie 2015). Marmots lose approximately 30% of body mass during hibernation (Bryant and McAdie 2003).

Population Spatial Structure and Variability

Spatially, the Canadian distribution of Vancouver Island Marmot is composed of four geographically isolated sub-populations. Each sub-population is composed of a cluster of 1–14 mountains, with each mountain home to one or more colonies.

Genetic variation within Vancouver Island Marmot is low compared to other species of marmots (estimated heterozygosity (He) 8–23%; Kruckenhauser *et al.* 2009) which implies the population has been small for an extended period. Records based on tagging (Bryant 1990, 1998), radio-telemetry (Bryant and Page 2005) and genetics (Kruckenhauser *et al.* 2009) indicated that prior to active management, spatially adjacent marmot colonies were connected through occasional dispersal movements. Marmots at a geographically disjunct mountain (Mount Washington), however, had been isolated for at least several generations based on DNA analysis (Kruckenhauser *et al.* 2009).

Even though there was evidence of at least two genetically distinct, geographically isolated subpopulations (Strathcona and Nanaimo Lakes), the risk of future inbreeding depression associated with low genetic diversity led to the decision to maximize genetic diversity by cross-breeding individuals from the two subpopulations in the captive-breeding program (Kruckenhauser *et al.* 2009). This approach continues to be recommended based on an analysis of re-introduction successes and failures of the Alpine Marmot (*Marmota marmota*), an actively managed marmot species in Europe (Bichet *et al.* 2016).

Designatable Units

Vancouver Island Marmot is considered to be a single designatable unit in Canada. The species is endemic to a portion of Vancouver Island with a patchy distribution of individual colonies that historically were linked by dispersal. There is no morphological, ecological or genetic evidence to suggest that individual colonies or collections of colonies (i.e., subpopulations) represent evolutionarily significant units. The species is found in one National Ecological Area (Pacific) and no subspecies designation is currently recognized under *M. vancouverensis* (Armitage 2014).

Special Significance

Vancouver Island Marmot is one of only five endemic species of mammal in Canada (Naughton 2012). From an evolutionary standpoint, Vancouver Island Marmot is significant in that despite having low genetic divergence from its sister species, the Hoary Marmot, morphologically it is one of the most distinct species of marmots (Cardini *et al.* 2005, 2009). Vancouver Island Marmot was hunted by Indigenous people as evidenced by cut marks on marmot bones found at four archeological cave/rock shelter sites on Vancouver Island (Nagorsen *et al.* 1996). This is consistent with the widespread use of other species of *Marmota* by Indigenous groups across mainland North America (Kuhnlein and Humphries 2017).

DISTRIBUTION

Global Range

Vancouver Island Marmot is endemic to Vancouver Island, British Columbia, Canada. This species is held at the Calgary and Toronto zoos for captive-breeding purposes.

Canadian Range

<u>Wild population</u>

Apart from captive animals, Vancouver Island Marmot is restricted to Mountain Hemlock and Coastal Mountain-heather Alpine Biogeoclimatic Ecosystem Classification zones on Vancouver Island, British Columbia (Nagorsen 1987, 2005; B.C. Conservation Data Centre 2017a). Currently, ~ 60% of active colonies are in the Mountain Hemlock and 38% are in Coastal Mountain-heather Alpine zones (Thelin *et al.* 2018).

Between 1972 and 1995, marmots or fresh burrows were reported from 15 mountains (Bryant and Janz 1996). Before reintroductions began in 2003, the range of Vancouver Island Marmot had contracted to only six mountains in the Nanaimo Lakes region of central Vancouver Island, and on Mount Washington, approximately 95 km to the northwest (Figure 1). Release of captive-born marmots to these and additional mountains has resulted in the species successfully occupying 31 different mountains in recent years; 17 mountains in the Nanaimo Lakes area, 12 mountains in the Strathcona Park area, and one mountain each in Schoen Lake and Clayoquot Plateau (Figure 2). Successful reproduction has been confirmed at 21 mountains since 2010 (Appendix 1), including areas that were re-established through releases of captive-born marmots.

In 2016, there were active marmot colonies on 25 mountains; 21 of these were confirmed to have marmots in 2017 while the other four were believed to still be active even though there was insufficient survey effort in 2017 to confirm marmot presence.

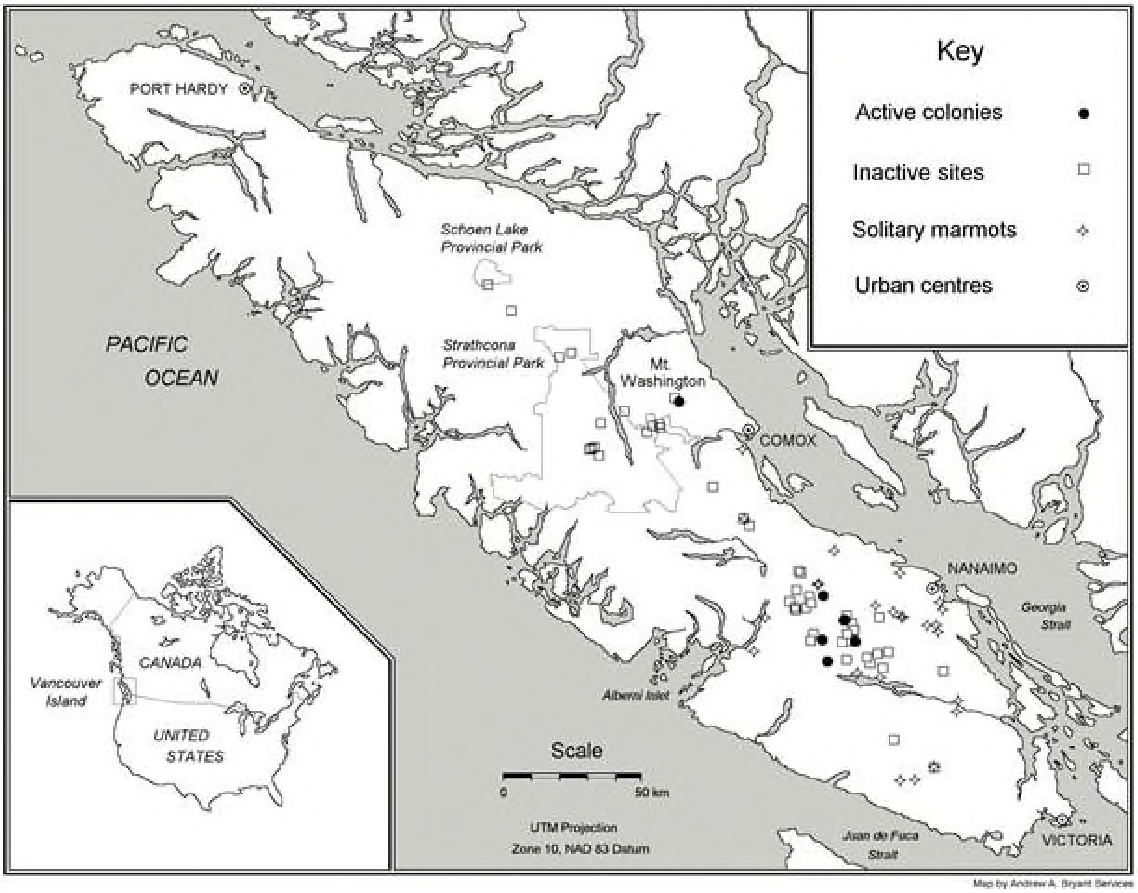

Figure 1. Historical distribution of Vancouver Island Marmot and active colonies in 2008. Inactive colonies illustrate colony records from 1896–2006. Solitary marmots likely represent dispersing individuals.

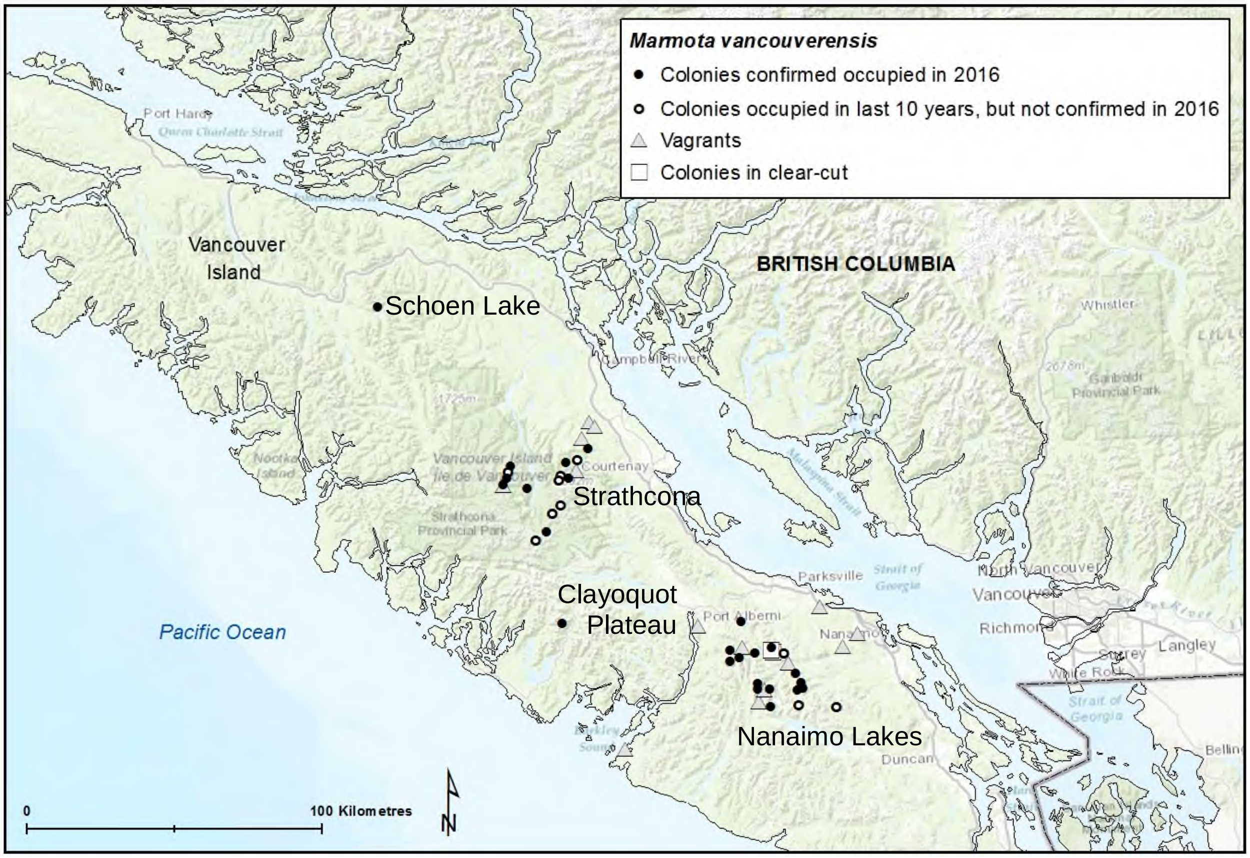

Figure 2. Current distribution of Vancouver Island Marmot. “Vagrants” were solitary marmots that likely represented dispersing individuals. When possible, vagrants and marmots in colonies in clear-cuts were translocated to other colonies.

Captive population

The captive-breeding population is housed at the Calgary Zoo in Calgary, Alberta, the Toronto Zoo in Toronto, Ontario, and the Tony Barrett Mount Washington Marmot Recovery Centre on Vancouver Island. The Mount Washington Recovery Centre was a captive breeding facility from 2001–2012. From 2012–2017, marmots were not bred at the Mount Washington Recovery Centre, but the Centre temporarily housed captive marmots scheduled for release. Some marmots were held overwinter and during the active season while others were held for a quarantine period of at least 30 days before release (Jackson *et al.* 2015). In fall 2018, the Mount Washington Recovery Centre re-opened as a year-round captive breeding facility. A fourth facility, the Mountain View Conservation and Breeding Centre in Langley, British Columbia, housed and bred Vancouver Island Marmot from 2000–2013. The Mountain View facility was phased out of the captive-breeding program because of fiscal constraints (Vancouver Island Marmot Recovery Team 2017). Captive marmots held within a facility were not considered when evaluating the quantitative assessment criteria.

Extent of Occurrence and Area of Occupancy

Based on all hibernacula and colonies that have been occupied within the last 10 years, the extent of occurrence was 5,653 km² (Figure 3). Using these same occurrences, the index of area of occupancy (IAO) based on a 2 X 2-km grid was 248 km^2.

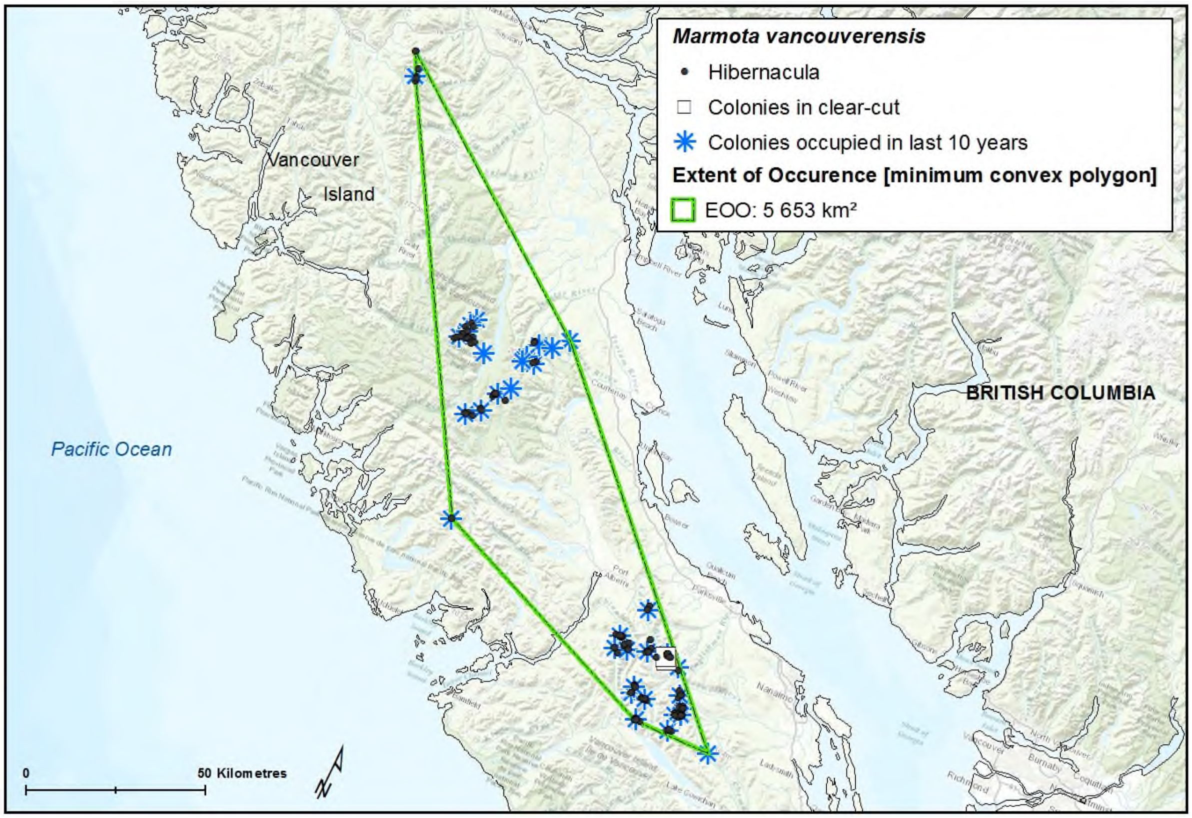

Figure 3. Extent of occurrence (EOO) for Vancouver Island Marmot based on successful hibernacula and colony occurrences. Only 27 and 19 marmots have been released at the Schoen Lake (most northerly colony on map) and Clayoquot Plateau (most westerly colony on map) locations. Data courtesy of the Marmot Recovery Foundation.

Search Effort

In 1972, naturalists, government personnel, and researchers began surveying mountains on Vancouver Island for marmots, which until that date were known from only a handful of museum specimen records (Bryant and Janz 1996). A survey of 97 mountains with each classified in terms of habitat suitability for marmots was also conducted by Routledge and Merilees (1980). The last “new” wild marmot colony was discovered in 1985.

The detection probability of marmot colonies is relatively high, as the species is large, vocal, diurnal, and the burrows are easy to identify. In addition, emergence holes in the snow during the spring are easily identifiable and can often be spotted from the air. However, the subalpine habitat in which marmots live is often remote and inaccessible to people, thus, there is always a chance of finding additional mountains occupied by a few marmots. Also, colonies that become established in high-elevation cut-blocks may not be detected because they occur on private land where public access is restricted; annual marmot surveys by researchers are not routinely conducted in cut-blocks unless known to be occupied. The likelihood of finding additional, large colonies of marmots in natural habitat is low.

Systematic annual population counts began in 1979 (Munro *et al.* 1985). Intensity and extent of surveys varied from year to year; the smallest effort occurred in 1975, when a single colony was visited on one day, and the greatest effort occurred in 1997, with 242 visits to 37 colonies. Between 1972 and 2006, population counts represented 1569 site-year combinations and provided data on minimum numbers of adults, yearlings and pups at 49 colonies.

Since at least 2007, annual surveys have focused on occupied and recently occupied mountains, but high public awareness of Vancouver Island Marmot and its identifiable physical characteristics means that marmots typically are detected if they establish outside the survey areas. Annually, backcountry hikers and Vancouver Island residents report marmot sightings to provincial biologists and the Marmot Recovery Foundation (Jackson pers. comm. 2017a). Forestry companies also ask their workers to report any marmot sightings (Lindsay pers. comm. 2017). Marmots found in unsuitable habitat (e.g., cut-blocks) are relocated to currently or recently occupied colonies or taken into the captive-breeding program. In 2016, two pups were removed from cut-blocks and taken into captivity and another dispersing marmot was trapped in a cut-block and translocated to natural habitat (Jackson pers. comm. 2016a). In 2017, five marmots (one adult female and four yearlings) in cut-block colonies and one dispersing marmot were trapped and moved to natural colonies (Jackson pers. comm. 2017a). New colonies that are found in natural habitat are monitored if possible; marmots are only translocated if they are unlikely to have access to a mate (Vancouver Island Marmot Recovery Team 2008).

HABITAT

Habitat Requirements

Vancouver Island Marmot requires deep colluvial soils; these loose, unconsolidated sediments found at the bottom of steep slopes are suitable for burrow construction. The species also requires suitable grass-forb vegetation to eat and microclimatic conditions that permit summer foraging and winter hibernation (COSEWIC 2008). Vancouver Island Marmot lives at high elevation, 700–1500 m above sea level. Natural habitat consists of subalpine meadows that generally occur at 900–1500 m, normally on steep (30–45°) south- to west-facing slopes (Bryant and Janz 1996), although a recent analysis using GIS and hibernacula spatial data estimated that up to 60% of current colonies may be located on slopes of less than 30˚ and >25% of slopes may have an easterly aspect (Thelin *et al.* 2018). Natural subalpine meadows are thought to be created and maintained by avalanches, slow movement of snow downhill (i.e., snow-creep), fire or a combination of those processes (Milko and Bell 1986). Most natural meadows occupied by Vancouver Island Marmot during 1972–2006 encompassed only a few hectares (Bryant and Janz 1996). Talus slopes, used as protection from predators and weather, and rocky outcrops or boulders, used for resting and vigilance, are typically found in the habitats that marmots occupy (Heard 1977, Bryant and Blood 1999).

Marmot colonies have been found as low as 700 m in human-altered habitats, such as cut-blocks and ski runs that mimic subalpine meadows (Bryant and Janz 1996). Cut-blocks are ecological traps with colonies going extinct 10 years after colonization (median value, range from 5–19 years; Vancouver Island Marmot Recovery Team 2008). In comparison, marmot colonies have persisted since at least the 1940s on ski runs, where ingrowing vegetation is cleared on a regular basis and high levels of human activity may deter predator use (Bryant 1998, Vancouver Island Marmot Recovery Team 2008).

Habitat Trends

The habitat of Vancouver Island Marmot is naturally fragmented, consistent with the spatial distribution of patches of high-elevation subalpine ecosystems (Bryant 1998). When dispersing between mountains, Vancouver Island Marmot must travel through lower-elevation forests. The degree of fragmentation in this lower-elevation matrix is variable and is affected by the amount of forest harvesting, anthropogenic development, and protected areas. Historically (1972–2006), most occupied marmot habitat was on private land that had been heavily modified by logging that began in the late 1940s and accelerated rapidly during the 1960s and 1970s (Bryant 1998). Less than 15% of the primary forest remains, and most of it is above 900 m. The result is a landscape with progressive replacement of mature forests with younger ones, combined with a growing number of logging roads.

Thelin *et al.* (2018) estimated that only 9.6% of Vancouver Island is currently covered by suitable marmot habitat. Bryant (1998) concluded that natural subalpine meadows comprised ~1% of the ~1000 km² Nanaimo Lakes core area. Subalpine habitat is even rarer south of Lake Cowichan and in areas such as Strathcona Provincial Park (Bryant 1993). Given the low abundance of Vancouver Island Marmot, currently there is sufficient habitat for population growth, and most of the suitable habitat is protected (see Habitat Protection and Ownership). Tree ingrowth has occurred at some of the subalpine meadows in which marmots live, but habitat management in the form of manual clearing of trees has occurred and is feasible for small areas (Marmot Recovery Foundation 2016a, Vancouver Island Marmot Recovery Team 2017).

Long term, the amount of natural habitat available to Vancouver Island Marmot is decreasing; climate change has resulted in forests replacing subalpine meadow habitat. Prehistoric bones of Vancouver Island Marmot recovered from caves and archaeological digs indicated that the geographic range has shrunk over the last few centuries or millennia

(Calvert and Crockford 1983, Nagorsen *et al.* 1996). This trend is supported by data on tree growth (Laroque *et al.* 2001) and pollen deposition (Hebda *et al.* 2005). Vancouver Island Marmot was apparently more widely distributed, and presumably more abundant, during warmer and drier conditions that prevailed over several periods in the past. The trend of decreasing habitat is expected to continue with a prediction that under a “worst case” scenario up to 97% of current marmot habitat may disappear by 2080. This is the result of a warming temperature that induces the growth of forests at higher elevations and a decrease in depth of winter snow pack, which is important for overwinter survival of marmots (Thelin *et al.* 2018).

BIOLOGY

Vancouver Island Marmot shares many life history characteristics with other alpine marmots; they are social, rely on a burrow system for protection from predators and adverse weather, and all have a predictable annual cycle highlighted by a hibernation period and an active season (Barash 1989, Amritage 2014). Armitage (2014) classified Vancouver Island Marmot as having a restricted family social system characterized by social groups composed of one male marmot, one to three females, their yearlings, and young; group hibernation; and dispersal by two-year-old individuals. Most recent colonies in natural habitats are small, typically containing one or two family groups and fewer than five adults (Bryant and Janz 1996).

Life Cycle and Reproduction

Like other alpine-dwelling marmots, Vancouver Island Marmot is relatively long lived and reproduces infrequently (Bryant 2005). Between 1997 and 2016, captive marmots lived to an average age of 6.4 years for males (range = 0.1–11.5) and 8.2 for females (range = 0.1–14.6; McAdie pers. comm. 2017).

Males and females may become sexually mature at age two, but most females do not breed until they reach three or four years of age (mean = 3.6 years, SD = 1.2, n = 16). There have been three instances where yearling females have bred and successfully weaned litters in captivity; yearling males have never bred in captivity (Table 1).

Table 1. Breeding success of Vancouver Island Marmot in captivity as a function of age. Summary was restricted to the years 2005–2017 as these are the years for which pairs were managed in a consistent way. Yearlings were typically maintained in group situations, thus, the exact number of unsuccessful pairings involving female yearlings could not be determined but there were three instances where yearling females gave birth to litters. Data courtesy of the Marmot Recovery Foundation.

	Males		Females	
Age	**n**	**% successful**	**n**	**% successful**
1	0	n/a	unknown	3 instances
2	61	29.5	68	26.5
3	63	44.4	68	33.8
4	65	46.2	58	53.4
5	61	44.3	47	46.8
6	48	52.1	41	53.7
7	43	44.2	31	58.1
8	34	47.1	27	33.3
9	25	24.0	26	50.0
10	19	10.5	23	34.8
11	5	0	19	26.3
12	0	n/a	11	9.1
13	0	n/a	4	25.0
14	0	n/a	1	0.00
Total	**424**	**40.3**	**424**	**40.3**

Female marmots are induced ovulators (Keeley *et al.* 2012); mating generally occurs during the time of emergence from hibernation in late April or early May. Vancouver Island Marmot is not strictly monogamous and numerous cases of polygyny have been reported (Bryant 1998). Gestation is 30–32 days (Keeley *et al.* 2003). In captivity, 40.3% (95% C.I. 35–45%, n = 424) of breeding pairs successfully wean litters (Figure 4). Litter size at weaning varies from 1–7 pups per litter in the wild population (mean = 3.4, SD = 1.1, n = 58; Bryant 2005) and is the same in captivity (mean = 3.39, n = 167; Jackson *et al.* 2015). In the wild population, the sex ratio of weaned pups does not differ from 1:1, but the sex ratio for captive weaned pups is slightly male-biased (55% males, n = 167 litter; Jackson *et al.* 2015).

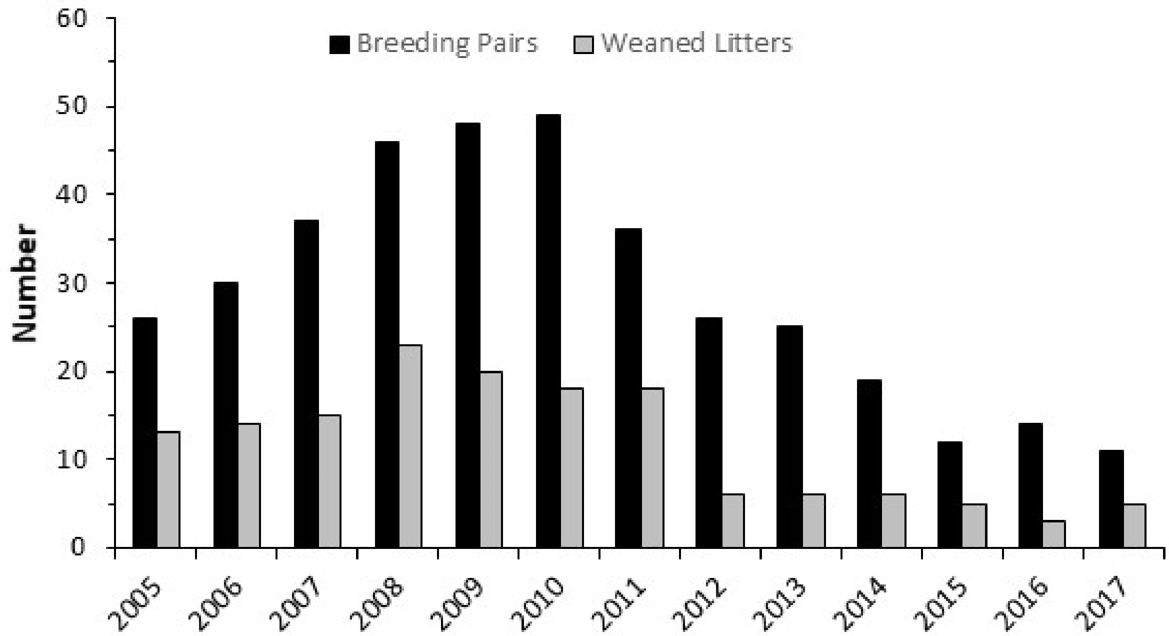

Figure 4. Breeding success, as measured by number of litters, of Vancouver Island Marmot in captivity. Data courtesy of the Marmot Recovery Foundation.

In captivity the probability of weaning a litter varies with age, with two-year-olds producing fewer litters than older adults (Table 1; Bryant 2005). This trend has also been observed in the wild population (Bryant 2005). The oldest age at which Vancouver Island Marmot has bred successfully in captivity is 13 years old for females and 10 years old for males.

In the wild population, females can wean pups in consecutive years but most successfully wean litters only every second year (mean between-litter interval = 1.9 years, SD = 0.7, n = 17; Bryant 2005). Not surprisingly, there is considerable annual variation in reproduction in the wild population (Figure 5, Table 2). Providing supplemental food (Mazuri® leaf-eater biscuits) in the spring was correlated with high reproduction at one mountain; supplemental feeding at several mountains has continued (Jackson *et al.* 2015) with five mountains receiving supplementation in 2017 (Jackson pers. comm. 2017a). The positive impact, if any, of providing supplemental food on marmot survival and reproduction has not yet been quantified.

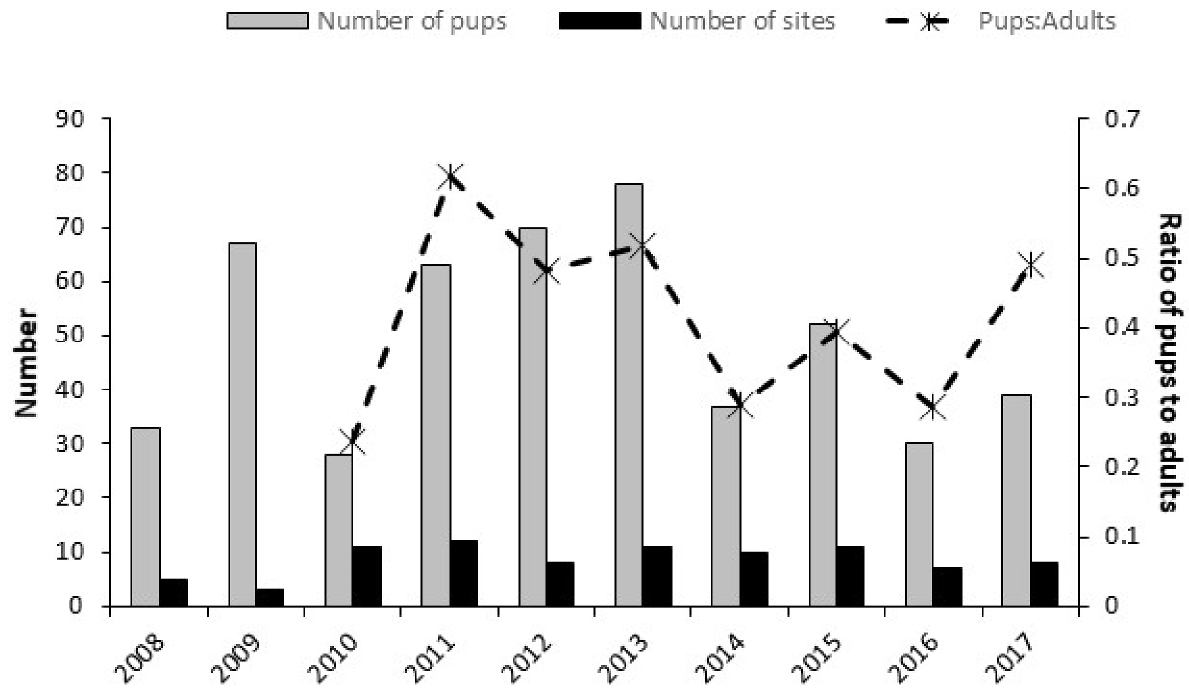

Figure 5. Reproduction of Vancouver Island Marmot in the wild. The number of pups is the minimum number of pups that were weaned in the wild, and the number of sites is the minimum number of mountains at which weaned pups were observed. Not all colonies and mountains were visited in all years and search effort and efficiency varied among years; thus values in figures should be considered an index. Data courtesy of the Marmot Recovery Foundation..

Table 2. Reproduction of Vancouver Island Marmot in the Nanaimo Lakes subpopulation. Search effort in this area was high and consistent among years, and thus provides a more accurate representation of yearly variation in reproduction than Figure 5. When calculating pups per breeding-aged female, the average of the minimum and maximum of breeding-aged females was used. Data courtesy of the Marmot Recovery Foundation.

Year	Minimum no. of colonies with pups	No. of breeding aged females (min–max)	Min. no. of pups	Average pups per breeding-aged female
2012	9	27–38	61	1.88
2013	9	21–34	64	2.33
2014	4	19–22	16	0.78
2015	8	16–23	35	1.79
2016	4	15–16	13	0.84
2017 [1]	5	11–11	22	2.00

[1] Data as of end of August 2017. All 2017 values may be an underestimate.

Use of Burrows

Vancouver Island Marmot constructs burrows in which they hibernate, bear and raise young, hide from predators, and shelter from adverse environmental conditions (Bryant and Blood 1999). Burrows (including hibernacula) are commonly re-used over multiple years by the same individuals and social groups (Bryant 1998). Several burrow systems have been occupied for over 30 years. Escape-burrows to avoid predators include shallow excavations under a rock or tree root. Burrows used overnight, or as birthing chambers are more elaborate, often with multiple entrances. As with escape burrows, they typically occur under boulders or a tree-root system. Hibernacula are presumably deep enough to reach below the frost line.

Diet

Martell and Milko (1986) identified plants eaten by Vancouver Island Marmot from fecal samples collected at three colonies. They concluded that marmots depended on Timber Oatgrass (*Danthonia intermedia*) and sedges (*Carex* spp.) in early spring, with a shift to forbs, especially Broad-leaved Lupine (*Lupinus latifolius*) and Sunflower (*Eriophyllum lanatum*) in summer and fall. Spreading Phlox (*Phlox diffusa*) is important in early summer.

Diet at other colonies is unknown. Food plants observed at low-elevation cut-block colonies included grasses, Pearly Everlasting (*Anaphalis margaritacea*), wild strawberry (*Fragaria* spp.), Fireweed (*Chamaenerion angustifolium*), and Broad-leaved Lupine (Bryant 1998).

Physiology and Adaptability

Wild Vancouver Island Marmot typically hibernate for approximately 210 days (mean immergence = 1 October, 95% CI = 28 September–3 October, n = 49; mean emergence = 28 April, 95% CI = 26–30 April, n = 43; Bryant and McAdie 2003). Duration of hibernation is significantly shorter in captivity (Bryant and McAdie 2003). During hibernation, body temperature is close to 5º C and spontaneous arousals occur every 10–14 days. The warming and subsequent cooling that occurs during an arousal bout occurs over approximately 24 hours (McAdie pers. comm. 2018). In the active season, marmot body temperatures fluctuate between 34–39ºC (McAdie pers. comm. 2018); marmots adjust body temperature through their posture and use burrows and “resting” boulders to avoid overheating (Melcher *et al.* 1990).

Much has been written about the “adaptability” of Vancouver Island Marmot to a human-modified landscape (Munro *et al.* 1985). Many marmots colonized and reproduced successfully in human-altered habitats. These habitats, however, likely acted as ecological traps (Bryant 1996, 1998). Populations that colonized ski runs on Green Mountain and mine tailings at Mount Washington during the 1980s became extirpated. Marmots have persisted on ski runs at Mount Washington, possibly because clearings are maintained and human activities deter predators. Despite large amounts of potential habitat created by logging above 700 m, only a small fraction was ever colonized and colonies in cut-blocks became extirpated 5–19 years post-colonization.

Vancouver Island Marmot in captivity exhibit reproductive and many behavioral traits comparable to their wild counterparts (Bryant 2005; Blumstein *et al.* 2006), although Werner (2005, 2018) reported that during the active season in which they were released, captive-released marmots had a 50% smaller home range, engaged in more social interactions, and initially were warier (as measured by flight distance) than wild-born marmots. Stress levels of marmots, as measured by hair cortisol concentration, is lower for marmots living in captivity than marmots in the wild (Acker 2018). Captive-born marmots apparently adjust successfully when returned to the wild, eating grasses and flowers, gaining mass, whistling when predators approach, digging burrows and hibernating at appropriate times (Bryant 2007). Stress level, as measured by hair cortisol, is higher, however, for newly released captive-born marmots (Acker 2018). In addition, during their first hibernation in the wild, captive-born marmots can have survival up to 75% lower than wild-born marmots. If they successfully survive their first hibernation in the wild, overwinter survival in subsequent years is similar to that of wild-born marmots (Jackson *et al.* 2016).

Dispersal

Like many other species of alpine-dwelling marmots, Vancouver Island Marmot has a population structure in which dispersal among high-elevation habitats is important in maintaining gene flow (Armitage 2014). Records based on tagging (Bryant 1990, 1998), radio-telemetry (Bryant and Page 2005) and DNA analysis (Kruckenhauser *et al.* 2009) suggest that the colonies in the Nanaimo Lakes region were connected through occasional dispersal movements.

Dispersers are most frequently two-year-old males and females. The maximum straight-line dispersal distance recorded for a wild-born marmot is 31 km although in 2015 an untagged adult male Vancouver Island Marmot was trapped in Bamfield, greater than 60 km from the nearest known colony (Marmot Recovery Foundation 2015, Pendergast pers. comm. 2015). Most dispersal distances, however, are less than 10 km (Table 3). Captive-release marmots move up to 20 km from the release site the year they are released (Table 3).

Table 3. Records of dispersal of wild-born marmots or captive-born marmots in the years following their release. Captive-born marmots were not introduced until 2003. Only data where age and sex and/or distance was reported are included.

Source	Age and Sex	Straight-line Distance
Heard 1977	Mature male	0.9 km
Bryant 1998	2-year-old male	7.4 km
	2-year-old male	5.9 km
	Prob. 2-year-old, female	7.4 km
Jackson and Doyle 2013	1-year-old female	
	1 or 2-year-old female	
	2-year-old male (X6)	
	2-year-old female	
	2 or 3-year-old male (X2)	
	2 or 3-year-old female	
	3-year-old male	
Jackson *et al.* 2014	2-year-old male	
	Prob. 2-year-old male	
	Male	31 km
	2-year-old female	11 km
Jackson and Lester 2015	1-year-old	4 km
	Not reported (X5)	3.5 km, 8 km, 12km, 14 km, 14 km, 22 km
Jackson 2016	Not reported (X4)	2.5 km, 2.5 km, 4.5 km, 6 km

Interspecific Interactions

Vancouver Island Marmot is opportunistic prey for Cougar, Grey Wolf, and Golden Eagle. Marmots commonly react to these species, as well as small raptors, deer, and elk, which pose no threat, by whistling or by fleeing into burrows. Vancouver Island Marmot is an important host to some parasite species and is the only known host of the tapeworm *Diandrya vancouverensis* (Mace and Shepard 1981) and may also be a host to a genetically unique intrafollicular mite and a *Mycoplasma* species (Vancouver Island Marmot Recovery Team 2017).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Between 1972 and 2006, population surveys resulted in an estimate of the minimum numbers of adults, yearlings and pups at 49 colonies over 1569 colony years. Bryant and Janz (1996) estimated the accuracy of these surveys and found that count success was highly variable; success in detecting marmots depended on colony size, time of day, season, sex, age, and reproductive status. Although greater than 9 visits were necessary to obtain a near-complete count of marmots in a colony, two to four counts usually detected 65–75% of the animals present. They concluded that for colonies visited once, observers probably counted 40–60% of adults present, depending upon time of year. Count success was higher earlier in the active season when there was less vegetative cover. For most colony-year combinations with two or more visits in June and July, observers probably saw 66–78% of adults, and 75–89% of young. Confidence limits on these estimates are unreliable because of differences in coverage, visibility, observer experience, and count intensity.

Survey methods have changed over time, both because of increasing reliance on telemetry and declining populations. It is easier to count small numbers of radio-tagged marmots at a given colony than to count greater than 30 untagged marmots, or to read ear-tags using a spotting scope (Bryant 1996). Thus, count success has increased over time and population estimates since 2000 likely approach a true census.

Visits to most known colonies occur annually, with the number and duration of visits being variable. For example, in 2017, field crews of one to eight people visited 16 of the 25 mountains known to have active marmot colonies. Each colony was visited 1–49 times (median = 6.5, n = 16; Jackson pers. comm. 2017b). In addition to colony visits, marmots with radio transmitters were monitored using telemetry both from the ground and air for spring emergence, movements and survival, and entrance into hibernation (Vancouver Island Recovery Team 2017). Most captive-born marmots that were released to the wild had radio transmitters (mean number released with transmitters = 31.1, SD = 25.61, n=16), and between 1992 and 2017, an average of 12.6 (SD = 12.9, n = 26) wild-born marmots were implanted with a radio transmitter for the first time. Each year, an average of 2.8 (SD = 3.3, n = 12) captive-born marmots and 2.8 (SD = 3.0, n = 24) wild marmots had their radio transmitters replaced because the transmitter batteries were at or past their life expectancy. Since at least 2010, wildlife cameras also were used to monitor marmot presence at colonies (MacDermott *et al.* 2010). These cameras often were set up to monitor feeders, which provided marmots with supplemental food in the early spring (Doyle 2011). In 2017, six colonies were monitored with wildlife cameras, with most colonies having one or two cameras.

Since 2010, a standardized method was used to estimate the number of marmots. The population count was the number of individuals known or thought to be alive. For each mountain, minimum and maximum numbers of individuals detected were determined. The minimum represented the number of unique individuals either seen by researchers or detected alive by telemetry during the active season. A marmot with a radio transmitter was excluded from the count if it was detected alive during the year, but its transmitter subsequently emitted a mortality signal prior to hibernation. The maximum number of individuals also included animals that were believed to be unique individuals, but there was a possibility that they were already counted. For example, a litter may have appeared to have six pups, but only four pups were observed during the field observation. The minimum number detected would include only the four pups, while the maximum number would include all six. The maximum number of individuals detected also included telemetered marmots that were detected within the past two years, but not the current year. The population count reported for each year was the average of the minimum and maximum number of individuals detected for that year. For the counts of the total population and mature marmots, the minimum and maximum values averaged 13.1% (SD = 6.1%, n = 8) and 15.2% (SD = 5.6%, n = 8) below and above the reported count, respectively.

The population counts included in this report excluded captive-born marmots in the year of their release. These captive-born marmots were included in the wild population count once they survived one hibernation in the wild. Captive-born marmots that survived their first winter in the wild typically bred and weaned wild-born offspring that contributed to population growth.

Abundance

The number of Vancouver Island Marmot counted in the wild in 2017 was 135 (min. = 127, max. = 142), of which 91 (min. = 86, max. = 95) were mature individuals (≥ 2-years-old), and 38 (min. = 37, max. = 39) were pups (Marmot Recovery Foundation, unpublished data). This number excluded 11 captive-born yearling marmots released in 2017 and three captive-born marmots that were released as yearlings in 2016 on Mount Washington and translocated in 2017; these individuals were excluded because they had not yet survived their first hibernation in the wild. Given the sampling effort and method, this is probably close to the total number of marmots in the wild population. Even though current inventory efforts focus on known occupied and recently occupied colonies, based on past search efforts (described under “Distribution”), it is unlikely that large colonies of marmots were not counted unless they were recently established colonies in cut-blocks that were not frequented by people. Cut-block colonies, however, would probably go extinct within 5–19 years (Bryant 1996, 1998).

At the end of 2017, there were 49 marmots in the captive population, including 19 pups. About half of these were mature animals. Although the captive population has a very young age structure, most captive-born marmots are released as yearlings. Therefore, many of the pups are not recruited into the captive population.

Fluctuations and Trends

Wild population

Vancouver Island Marmot colonies fluctuate in size from year to year and individual colonies can exhibit divergent population trajectories (COSEWIC 2008). Colonization of cut-block habitats during the 1980s led to dramatic changes in local marmot densities. Most colonization events occurred within 1–2 km of previously existing natural colonies (Bryant 1998), and most new colonies became much larger than those in adjacent natural habitats (COSEWIC 2008).

By the mid-1980s more than half of the known marmot population inhabited four adjacent mountains in the Nanaimo Lakes area, with most animals living in cut-blocks on Butler Peak, Haley Lake, Gemini Peak and Green Mountain. When the marmot population collapsed during the 1990s, it was often the areas with the highest density that declined first. Bryant (1998) suggested that these high local densities attracted predators. Monitoring of radio-tagged Cougar and Grey Wolf supported this hypothesis as some individual predators repeatedly returned to hunt in the same meadows. During the population collapse of the 1990s, the Haley Lake colony (Heard 1977, Bryant 1996) declined from 25 to 10 marmots in 1994–1995. The largest colony ever recorded, 39 animals (1994) in the Butler Peak “west roads” cut-blocks, was reduced to 15 individuals in 1995. Conversely, colonies in natural meadows with low densities and without adjacent cut-block colonies were more likely to persist. By the early 2000s the number of marmots in the Nanaimo Lakes area had fallen to ~ 30 individuals, with most living in low-density natural colonies on the periphery of their geographic range.

Through captive-born releases and reproduction of both captive-born and wild-born marmots, the wild population increased dramatically from ~ 85 in 2007 to almost 300 just seven years later in 2012 and 2013 (Figure 6). Between 2013 and 2017, the population declined every year at an annual rate of 3–30%. This rate included the recruitment of captive-released marmots into the wild population, so the rate of decline based on reproduction and survival of marmots in the wild population was even higher. The first two years of the most recent population decline, 2013–2015, were characterized by decline in the number of sub-adults (pups and yearlings). During that time the number of mature marmots remained at >120 (Figure 7). Between 2015 and 2017, however, the mature marmot population declined by >15% per year. The decline was associated with both low reproduction in the wild from 2014–2016 (Figure 5) and, in 2015/2016, atypically low overwinter survival in the Strathcona region (Marmot Recovery Foundation 2016b). These years corresponded to three years of summer drought conditions on Vancouver Island and relatively little supplementation with captive-bred marmots (Figure 6). In 2017, there was high Cougar predation at the Nanaimo Lakes subpopulation.

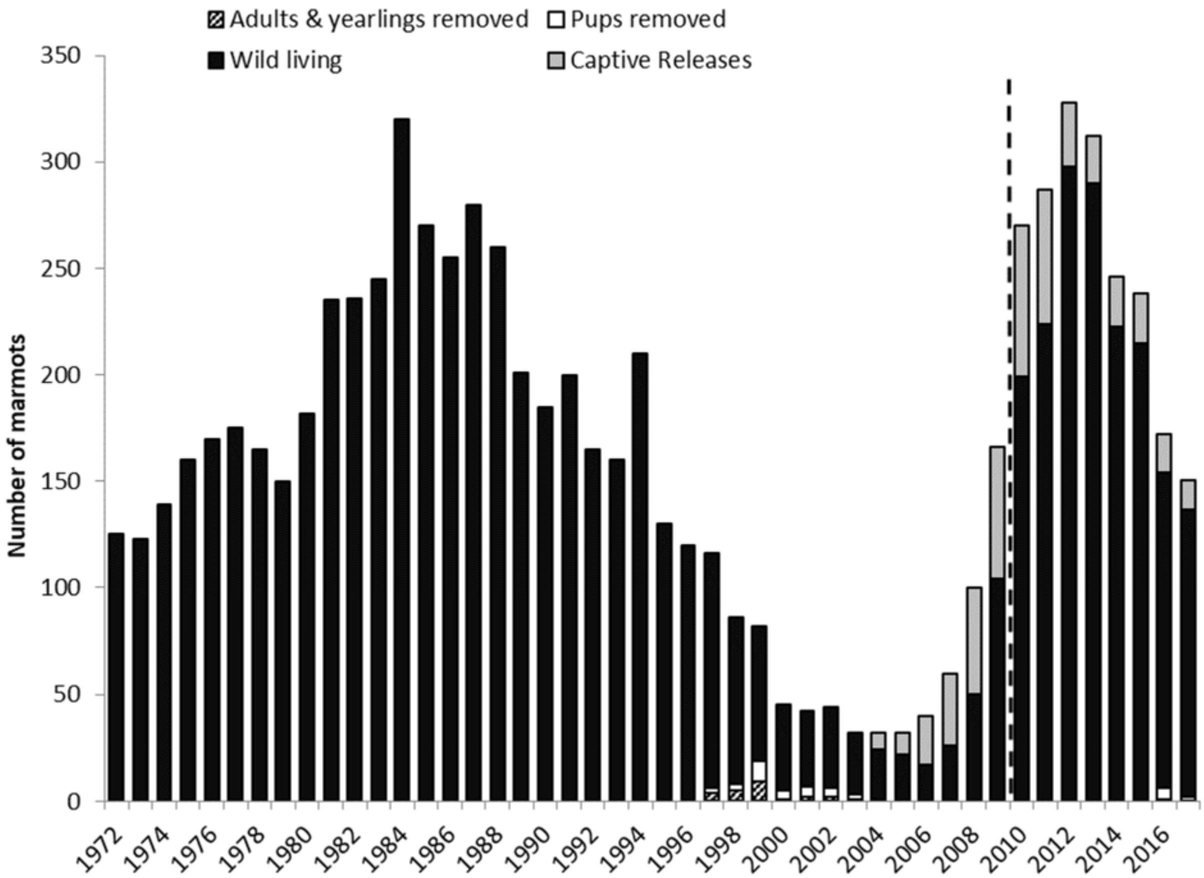

Figure 6. Population size of Vancouver Island Marmot. Wild living marmots included wild-born marmots and captive released marmots that survived at least one hibernation in the wild. Captive releases were marmots released to the wild that survived until their first hibernation. Marmots were removed from the wild to establish (1997–2004) and augment (2016–2017) the captive breeding population. Prior to 2010 (dashed line), methods used to estimate the population varied and thus may not be directly comparable; since 2010, a standard method has been used to determine the population estimate. Figure has been modified and updated from Jackson *et al.* (2015) with permission. Data for 2014–2017 courtesy of the Marmot Recovery Foundation and 1997–2004 removal data from COSEWIC (2008).

Table 4. Observed finite rate of increase ($\lambda = N_{t+1}/N_t$) for Vancouver Island Marmot where λ > 1 indicates the population is increasing, and λ < 1 indicates that the population is decreasing. For the entire population, the finite rate of increase includes the recruitment of captive-born marmots into the population once they have survived one hibernation in the wild (i.e., captive-born marmots released in 2010 are first considered part of the population in 2011 if they survived until then). There were no captive releases in the Nanaimo Lakes subpopulation from 2012–2017; therefore λ for the Nanaimo Lakes subpopulation is the result of reproduction and survival only. Data courtesy of the Marmot Recovery Foundation.

	Entire Population		Nanaimo Lakes Subpopulation	
	λ all ages	λ adults	λ all ages	λ adults
2010	1.13	0.86		
2011	1.33	1.42		
2012	0.97	1.04	1.22	1.21

	Entire Population		Nanaimo Lakes Subpopulation	
	λ all ages	λ adults	λ all ages	λ adults
2013	0.77	0.85	0.52	0.64
2014	0.97	1.03	0.96	1.00
2015	0.69	0.80	0.67	0.80
2016	0.91	0.86	0.99	0.72

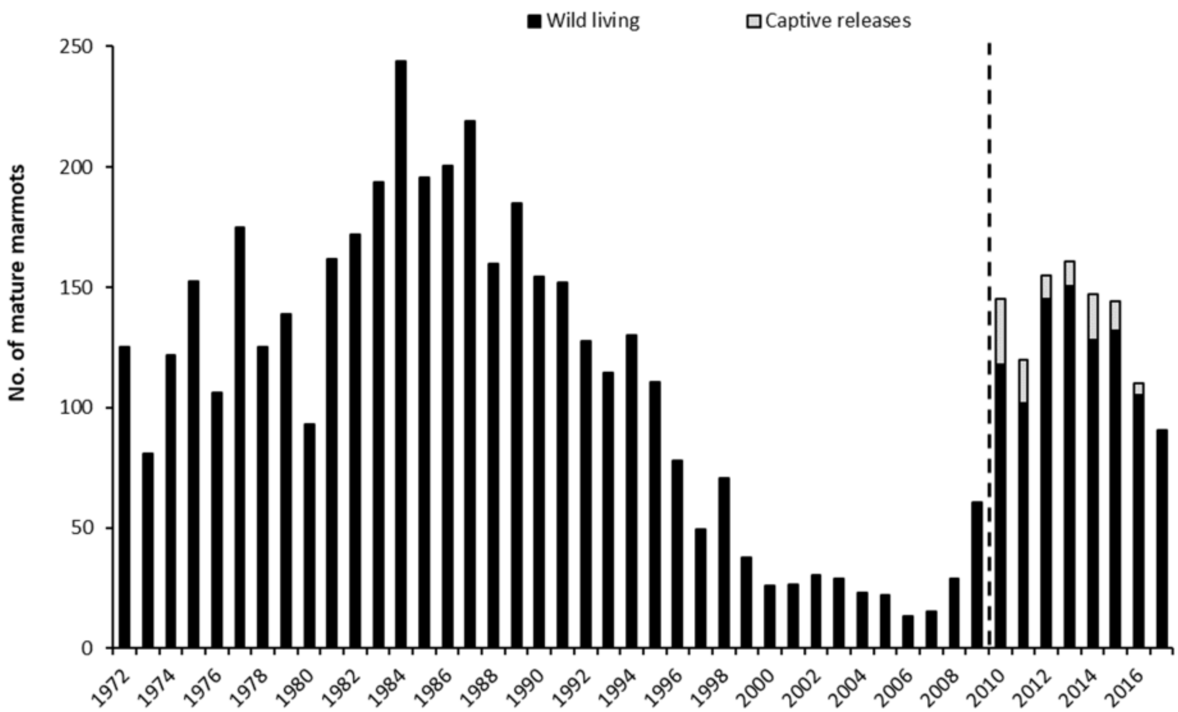

Figure 7. Approximate number of mature Vancouver Island Marmots. Prior to 2010 (dashed line), estimates were obtained by multiplying the total number of marmots by the percent of adults estimated from COSEWIC (2008; Figure 5, 1972–2006) or, for 2007–2009, the average percent of adults in the population from 2010–2017 (58%). Estimates from 2003–2009 do not differentiate between newly released captive-bred, established captive-bred, and wild-born individuals. Estimates for 2010–2017 were based on direct counts of adult marmots; wild living marmots included wild-born marmots and captive released marmots that survived at least one hibernation in the wild, while captive released were marmots released to the wild that survived until their first hibernation. Data for 2010–2017 courtesy of the Marmot Recovery Foundation.

The population decreases resulted in an average 50% reduction in the number of marmots per mountain. With the exclusion of Mount Washington, in 2013, there was an average 10.0 (SD = 10.3, range = 1–46, n = 29) marmots on each mountain where marmots were detected. In 2017, that had dropped to an average of 5.4 (SD = 5.0, range = 1–19, n = 23). Mount Washington had at least 47–58 marmots in 2013; this dropped to 31 in 2017.

In 2012, the decision to stop captive-born releases to the Nanaimo Lakes subpopulation was made. In 2013, supplemental feeding in the spring was also stopped. In the absence of management intervention, the number of mature marmots in the Nanaimo Lakes subpopulation increased by almost 20% between 2012 and 2013; this was followed by a major decline from 2013 to 2014. Since 2014, both total and mature numbers of marmots have continued to decrease (Table 4). In 2017, augmentation of the Nanaimo Lakes subpopulation with captive-released and wild marmots (translocated from cut-blocks) resumed; these individuals were not included in the 2017 numbers presented for Nanaimo Lakes.

The three-generation population trend (2001–2017) for mature individuals was positive, but non-linear (Figure 7). This was the result of a distinct phase of population increase following a historic low in 2003 and then a decrease from 2012–2017. In total, the population increased by 288 or 284%, assuming exponential or linear growth, respectively. Considering just the first two generations, the population increased by 1332 or 731%. However, the population decreased by 78 or 66% over the past generation (2012–2017), again representing exponential and linear growth, respectively.

Population viability modelling

As part of an IUCN workshop, participants constructed a stochastic population model (PVA; *VORTEX* 10.0.8 Lacy and Pollak 2014) to explore recovery strategies for Vancouver Island Marmot (Jackson *et al.* 2015). Two models were constructed to explore the extremes in demographic rates observed for the Nanaimo Lakes subpopulation. The "healthy population" model ($\lambda = 1.07$) used survival rates estimated from when the subpopulation was stable or increasing (2003–2007 and 2011–2013), while the "declining population" model ($\lambda = 0.88$) used survival rates estimated from the years when the subpopulation was in decline (1987–2004).

The predicted population decline and resulting probability of extinction varied considerably according to scenarios that represented a combination of reduced mortality and various levels of supplementation through captive breeding. Predictions from the healthy population model suggested that the probability of extinction after 100 years (PE_{100}) was <1%, with a predicted mean population size of 215 ± 54.5 (SD) marmots (Jackson *et al.* 2015). The probability of extinction (PE_{100}) remained low across a range of values for carrying capacity and initial population size. In contrast, under the declining population model, PE_{100} was 100%. To maintain the initial population size under the declining population model, mortality rates would have to be reduced by 40%, or the population would require augmentation with 25 effective releases (i.e., captive-born releases that survive to the spring following their release) per year (Jackson *et al.* 2015).

Simulations for the PVA were generated for a 100-year period whereas Endangered status for Criterion E is assed relative to a five-generation period (~ 26 years). Considering Figure 9 in Jackson *et al*. (2015), a scenario of low survival and no supplementation resulted in extinction within approximately 38 years. This assumed a starting population of 202 individuals whereas there were 135 (min. = 127, max. = 142) marmots in the wild in 2017. A smaller starting population would achieve extinction earlier and 100% extinction greatly exceeds the 20% probability required to meet the criterion for Endangered. The stochastic intrinsic growth rate (r=-0.144; Table 3, Jackson *et al*. 2015) from that model resulted in an estimate of 3.19 marmots after five generations when starting with a population of 135 individuals.

Captive population

Marmots were first taken into captivity in 1997 to establish a captive-breeding program (Bryant 2005). A total of 63 marmots (25 adults and 38 pups) have been taken from the wild for that program (Figure 8). Fifty-five of these were brought into captivity from 1997–2004 and an additional eight wild-born marmots were brought into the captive population in 2016 and 2017 to increase genetic diversity in the captive population.

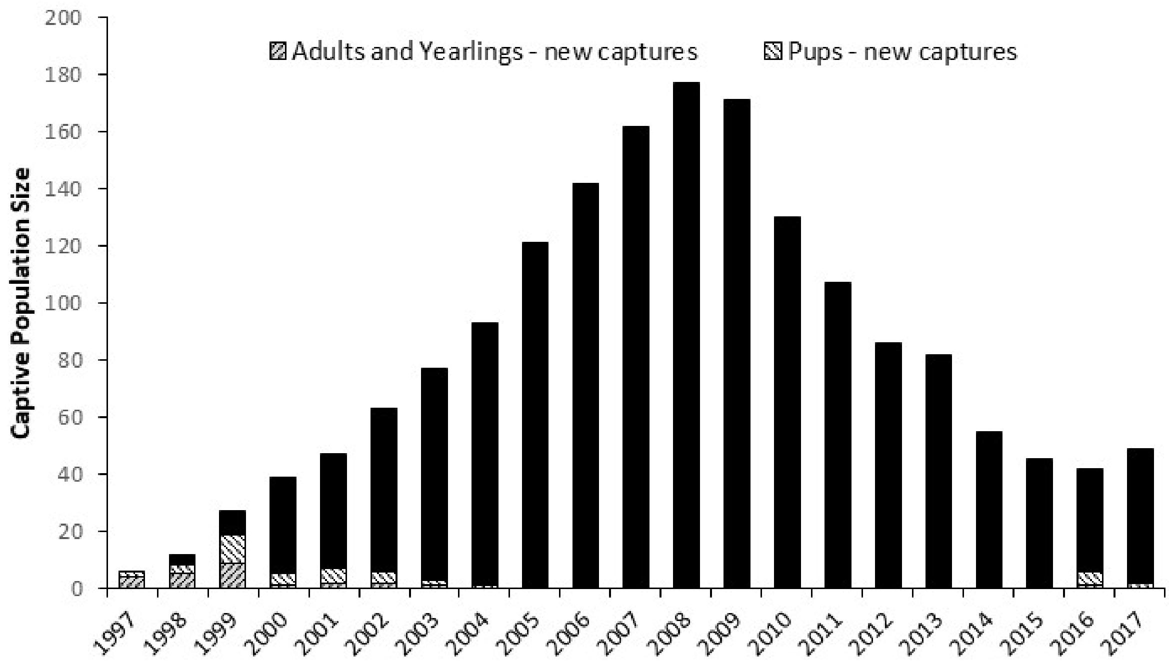

Figure 8. Population size of captive Vancouver Island Marmot. 1997–2016 data originally published in Vancouver Island Marmot Recovery Team (2017); figure updated and used with permission.

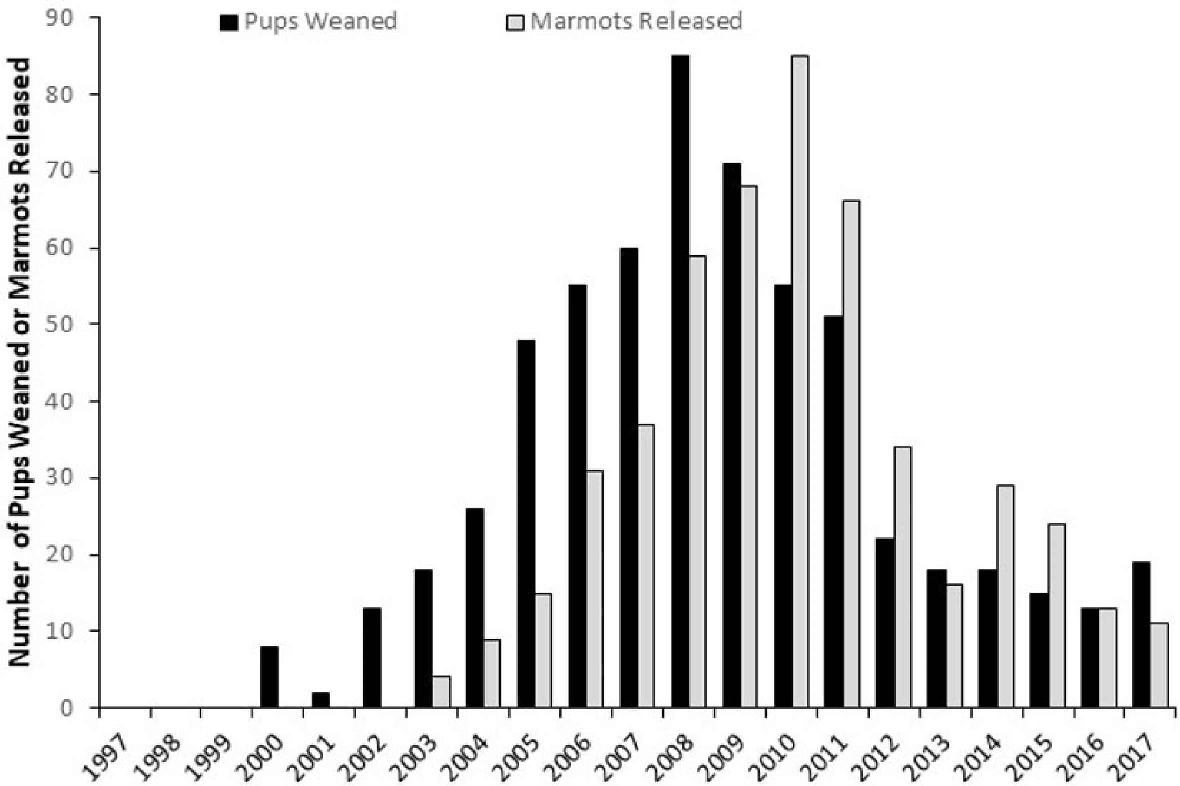

Figure 9. Numbers of captive-born Vancouver Island Marmot pups weaned and released. 1997–2016 data originally published in Vancouver Island Marmot Recovery Team (2017); figure updated and used with permission.

The first marmot pups were born in captivity in 2000 (Bryant 2005). The captive population grew from 55 to 177 individuals in 2008 (Figure 8), with the number of breeding pairs peaking at 49 in 2010 (Figure 4). At that time, the captive-breeding population was housed in four facilities. In 2017, there were 49 marmots in captivity, including 19 pups (Figures 8 and 9).

The captive-breeding program has facilitated the release of 4–85 marmots to the wild population annually since 2003 (Figure 9). The peak of 85 occurred in 2010 when the captive population was being downsized. From 2000–2017, the captive population weaned 597 marmot pups and from 2003–2017, 490 marmots were released. Nearly eight marmots (7.8) were released for every marmot brought into the captive population.

Rescue Effect

There is no possibility of a natural rescue effect as there are no wild populations of Vancouver Island Marmot outside Vancouver Island, British Columbia. Colonies experiencing a population decline may be rescued by dispersing individuals if there is an active colony within dispersal distance. Between 2006 and 2013, there were 10 natural dispersal events among the colonies in the Nanaimo Lakes subpopulation, with 50% of these dispersers eventually breeding where they settled (Jackson and Doyle 2013) and in 2015, two new mountains in the Strathcona subpopulation were naturally colonized by dispersers (Jackson and Lester 2015). The current low number of marmots, limited spatial distribution, and isolation of many colonies suggest that there is a low probability that an individual marmot colony experiencing a decline will be rescued naturally.

The captive population has mitigated declines in the wild population and can continue to do so. Results from the stochastic population model suggested that under conditions of high wild survival, captive-released marmots would not be required for demographic rescue. If the wild population experiences mortality rates observed during the 1984–2004 decline, ~ 25 effective releases (i.e., captive-released marmots that survived their first hibernation in the wild) would be required annually (Jackson *et al.* 2015). Overwinter survival of captive-released marmots in their first winter in the wild is <40% (Jackson *et al.* 2016), so to achieve ~ 25 effective releases, ~ 63 captive marmots would have to be released annually to reverse a severe decline. The ability of the captive population to rescue the wild population is limited primarily by the size of the captive population. The captive population was decreased in recent years for fiscal reasons; existing facilities are at capacity and produce 13–22 pups annually.

THREATS AND LIMITING FACTORS

Threats

The primary immediate threats to Vancouver Island Marmot are predation by native predators and ecosystem modification that results from logging and wood harvesting (based on the IUCN-CMP unified threats calculator; Vancouver Island Marmot Recovery Team 2017). Long-term shifts and alteration of habitat caused by climate change is predicted to pose a threat to the species. Additional threats that pose a Low or Negligible potential impact include roads and railroads, dams, introduced genetic material, and avalanches (Appendix 2; see also Vancouver Island Marmot Recovery Team 2017 for discussion of low and negligible threats impacts).

<u>Predation by native species (Problematic native species)</u>

The major immediate threat to Vancouver Island Marmot is predation by native species (Cougar, Grey Wolf, and Golden Eagle) with an estimated impact of High to Low. Predation is the proximate cause of mortality in the majority of wild and captive-release marmots (McAdie 2018) and is believed to be the proximate cause of population declines of the 1990s (Bryant and Page 2005). Annual survival rates declined between the 1980s and 2000s (COSEWIC 2008) and were much lower than during the population increase from 2011–2013 (Jackson *et al.* 2015). Losses at individual colonies can be dramatic within a single year, and spatially correlated among adjacent colonies (Bryant 2000). Indices of Cougar and Grey Wolf abundance on Vancouver Island increased between the early 1980s and 2000s (unpublished data, B.C. Ministry of Environment, Archibald *et al.* 1991), perhaps as a numerical response to deer populations (Bunnell 1990, Bryant and Page 2005). The 1980s and 1990s were also associated with a high abundance of Golden Eagles on Vancouver Island (McAdie pers. comm. 2016).

Grey Wolf and Cougar presence in marmot habitat is linked to the distribution of their primary prey, Columbian Black-tailed Deer and Roosevelt Elk. Both ungulate species use cut-blocks for foraging (Nyberg 1990). During the 1980s and 1990s, logging occurred at high elevation on Vancouver Island (Lindsay pers. comm. 2016). This may have drawn more deer and elk and their predators closer to marmot habitat, where the predators opportunistically preyed on marmots. Logging at high elevation near marmot habitat (i.e., >700 m) is therefore an indirect threat to Vancouver Island Marmot.

Ecosystem modification

Succession following logging poses a threat to Vancouver Island Marmot with an estimated impact of Medium. Although marmots will colonize cut-blocks, which mimic natural meadows, cut-block colonies persist only 5–19 years (Bryant 1996, 1998; Vancouver Island Marmot Recovery Team 2008). The extirpation of colonies in cut-blocks is not caused by marmot emigration; it is because predation of marmots in cut-blocks is higher than in natural habitat (Bryant 1996, 1998). Also, following normal successionary processes, including planting and regrowth of trees, cut-blocks become unsuitable as marmot habitat. Thus, cut-blocks at high elevation are considered sink habitat.

Vancouver Island Marmot continues to colonize high-elevation cut-blocks, with three cut-blocks found to be occupied between 2015 and 2018. Because cut-blocks are unsuitable habitat, the Vancouver Island Marmot Recovery Team translocates marmots that colonize cut-blocks to natural meadows (Jackson 2017a).

Habitat shifting and alteration because of climate change

Climate change is expected to reduce the amount of suitable habitat for Vancouver Island Marmot with an estimated threats impact of High to Low. Thelin *et al.* (2018) predicted the amount of current habitat on Vancouver Island and compared that to the availability of habitat following future climate change. Based on “worst case” climate change predictions (i.e. high emissions over the longest period), the model predicts that by 2080 there could be a 97% reduction in the amount of suitable marmot habitat. Increased temperature and drier summers are predicted to decrease the area of the Mountain Hemlock zone and the Coastal Mountain-heather Alpine Biogeoclimatic zone is predicted to disappear from Vancouver Island. In addition, there will be a decreased winter snow pack, which is required for successful hibernation, in many areas.

Vancouver Island Marmot is an obligate hibernator and requires specific winter microclimatic conditions. Climate change might influence the timing of hibernation. Emergence from hibernation of Yellow-bellied Marmot was correlated with the date of snowmelt at a study site in Colorado; in 2014 they were emerging 30 days earlier than in 1976 (Inoue *et al.* 2000, Armitage 2014). The vulnerability of Vancouver Island Marmot to predation might increase if they remain active later in the fall or emerge earlier in the spring. Werner (2005) reported that the mean date of marmot immergence into hibernation was almost three weeks later in 2002–2004 compared with 1973–1975 (but see also Bryant and McAdie 2003), which means they were susceptible to predation for a longer period. In years in which snow melt is late because of a heavy snow pack, studies on *Marmota* have reported decreased reproductive rates and lower survival of younger individuals (Armitage 2014), probably because later snow melt results in a shorter growing season (Van Vuren and Armitage 1991).

Limiting Factors

There are four limiting factors for Vancouver Island Marmot: low rate of reproduction, small population size, limited suitable habitat within dispersal distance of current colonies, and genetic isolation (Vancouver Island Marmot Recovery Team 2017).

Low rate of reproduction

Alpine marmots, including Vancouver Island Marmot, have low lifetime reproductive output compared to other rodents (Armitage 2014). As previously indicated, most Vancouver Island Marmot do not reproduce until they are at least three years old, the average weaned litter size is relatively small (3.4 pups), and on average, reproductively mature females successfully wean litters only every second year (Bryant 2005).

Small population size

Small populations of Vancouver Island Marmot are susceptible to stochastic events (Jackson *et al.* 2015). Also, there is evidence of an Allee effect when populations have fewer than 250 individuals (Brashares *et al.* 2010). Dispersal and gene flow are less for small colonies, increasing genetic drift and the potential for inbreeding depression.

Distance to suitable habitat

Despite the appearance of sufficient suitable habitat for marmots, much of this habitat is not within natural dispersal distance of extant colonies, making it inaccessible to wild marmots (Bryant and Janz 1996).

Genetic isolation

Genetic variation within Vancouver Island Marmot is low (Kruckenhauser *et al.* 2009), and there is anecdotal evidence that inbreeding may have contributed in the past to lower reproductive success at one isolated mountain (Mount Washington; Vancouver Island Marmot Recovery Team 2017). Although genetic variation of the wild population has increased through release of captive-born marmots and translocations, population modelling predicts that in the absence of captive-releases, inbreeding depression occurs (Jackson *et al.* 2015). The loss of genetic variation could be mitigated through occasional translocation of individuals between subpopulations.

Pedigree analysis suggests that 95% of the captive population's genetic diversity has been maintained (Figure 10; Carnio 2017). Of the 63 animals brought into the captive population, 38 have contributed genetically to the population, although the degree of contribution varies considerably (Carnio 2017). The captive population is currently smaller than that needed to maintain >90% of the original genetic diversity for an additional 5–10 years (predicted captive population size required = 80; Carnio 2017). Therefore, to increase genetic diversity in the captive population an additional seven individuals from the wild population were brought into captivity in 2016 and 2017 (Figure 8). Researchers are developing methods of cryopreservation of semen, semen collection, artificial insemination, and hormone treatment to stimulate reproduction in mature females that have not yet contributed pups (Jackson *et al.* 2015, Graham pers. comm. 2018); all would facilitate the maintenance of genetic diversity in the captive and wild population.

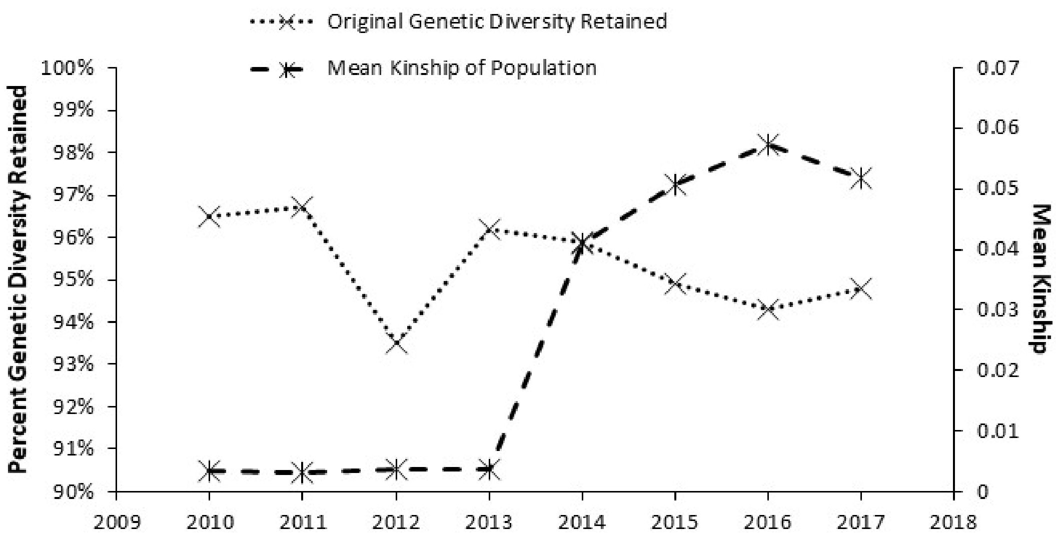

Figure 10. Maintenance of genetic diversity within the captive population of Vancouver Island Marmot. The increase in the genetic diversity between 2012 and 2013 in the absence of any additions of wild marmots to the captive population was because an older wild-caught female bred for the first time. The decrease in mean kinship in 2016 resulted from a yearling, brought into the captive population from the wild population in 2016, weaning pups in 2017. Data courtesy of the Marmot Recovery Foundation.

Number of Locations

Vancouver Island Marmot is found at four locations at which a single threatening event could rapidly affect all individuals at a location. Those locations represent four discrete geographic subpopulations that coincide with a single mountain (Schoen Lake and Clayoquot Plateau) or spatially clustered mountains (Nanaimo Lakes and Strathcona). The population at Schoen lake is very small and may be extirpated; this would result in three locations. The identified threats affect all locations, but the severity varies. Predators are present at all locations, but hunting of Cougars and Wolves is not permitted in Provincial

Parks, which suggests that the abundance of terrestrial predators may be higher at the three locations associated with Provincial Parks: Strathcona, Schoen Lake, and Clayoquot Plateau. In addition, individual predator behaviour can vary among locations. For example, in 2017, 12 mortalities were attributed to Cougar predation at the Nanaimo Lakes location, and a specific individual Cougar may have been responsible for most or all of the predation. Anecdotal evidence suggests that predation is less within colonies in the Strathcona location that are adjacent to ski facilities. In this case, human activity creates a refuge from predation. Because of their extremely small population size and isolation from other locations, marmots at the Schoen Lake and Clayoquot Plateau locations are more susceptible in the short term to the effects of environmental and demographic stochasticity and genetic isolation. If a disease outbreak occurred at any of the four locations, it could impact all the colonies at that location. It would not, however, be naturally transmitted among locations because the locations are geographically isolated and are not connected through natural dispersal movements.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

In April 1978, Vancouver Island Marmot was assessed as Endangered by COSEWIC (Munro 1978). Endangered status was reconfirmed in April 1997, May 2000, April 2008 (Bryant 1997, COSEWIC 2000, 2008), and May 2019. Vancouver Island Marmot is on Schedule 1 of the *Species at Risk Act* (SARA), and is also listed as Endangered (Schedule E) under the British Columbia *Wildlife Act*. They are designated as “Identified Wildlife” by the Province of British Columbia (Province of British Columbia 2004), which means they are given special management considerations under the British Columbia *Forest and Range Practices Act*. Vancouver Island Marmot within Strathcona, Clayoquot Plateau, and Schoen Lake Provincial Parks have additional protections extended to all wildlife in parks under the British Columbia *Park Act*. Finally, Vancouver Island Marmot is a foreign mammal listed under the U.S. *Endangered Species Act* (US Fish and Wildlife Service 1984, 2017).

Non-Legal Status and Ranks

Provincially, Vancouver Island Marmot is assigned a ranking of Critically Imperiled (S1) based on the NatureServe Conservation Status ranking criteria, and are on British Columbia’s Red List of extirpated, endangered, and threatened species in the province (BC Conservation Data Centre 2017b). Vancouver Island Marmot has been given a Conservation Framework Priority ranking of 1 by British Columbia, the highest rank possible. In 2017, the International Union for the Conservation of Nature (IUCN) assessed the species as Critically Endangered, a ranking that was also assigned in 2008 and 2013; prior to 2008, Vancouver Island Marmot had been assigned a rank of Endangered by the IUCN (Roach 2017).

Habitat Protection and Ownership

In addition to the habitat protection afforded to Vancouver Island Marmot by applicable provisions in Canada's *Species at Risk Act*, and the British Columbia *Wildlife Act* and *Forest and Range Practices Act*, the Haley Lake Ecological Reserve (888 ha) and the Green Mountain Wildlife Management Area (300 ha) were established to protect Vancouver Island Marmot habitat on land donated by forestry companies. Areas within the boundaries of the Haley Lake Ecological Reserve are protected from industrial resource extraction under the British Columbia *Ecological Reserves Act*, and marmot habitat within the Green Mountain Wildlife Management Area is protected under the British Columbia *Wildlife Act*. The British Columbia *Park Act* affords habitat protection to marmots living in Provincial Parks.

In cases where Vancouver Island Marmot colonies exist on crown land leased to forestry companies or private lands owned by forestry companies or alpine resorts, the lands are managed with active and ongoing consultations among the lease or land owner, the Marmot Recovery Foundation and the Vancouver Island Marmot Recovery Team (Vancouver Island Marmot Recovery Team 2017).

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED

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BIOGRAPHICAL SUMMARY OF REPORT WRITER

Elizabeth Gillis is a professor of wildlife biology in the Department of Resource Management and Protection at Vancouver Island University. She obtained her B.Sc. from the Nova Scotia Agricultural College (1994), and her M.Sc. and Ph.D. from the University of British Columbia (1998, 2004).

Her past research involved the population dynamics and behaviour of microtine rodents (Nova Scotia), Snowshoe Hares (Yukon), Arctic Ground Squirrels (Yukon), and American Dippers (British Columbia).

Dr. Gillis has been a member of the Vancouver Island Marmot Recovery Team since 2008.

COLLECTIONS EXAMINED

The following museums have Vancouver Island Marmot specimens in their collections. Records from these collections were examined to confirm that they were all collected from areas known to have marmots currently or historically.

Canadian Museum of Nature, Ottawa, Ontario

Royal Ontario Museum, Toronto, Ontario

UBC Beatty Biodiversity Museum, Vancouver, British Columbia

Vancouver Island University Museum of Natural History, Nanaimo, British Columbia

Museum of Vertebrate Zoology, Berkeley, California

Appendix 1. Reproduction of Vancouver Island Marmot by mountain; shaded blocks indicate reproduction was confirmed by the observation of pups that year or yearlings the following year. Search effort and the mountains surveyed varied from year to year, so the absence of confirmed reproduction does not necessarily mean there was no successful reproduction. "▲" denotes a mountain that had a typical survey effort but no pups were detected. "■" indicates the most recent year adult marmots were confirmed at mountains where adults were not confirmed in 2016.

	2010	2011	2012	2013	2014	2015	2016
Nanaimo Lakes							
Arrowsmith					▲		
Butler							
Buttle				■			
Douglas					▲		
Gemini							
Green					▲		
Haley							
Heather					▲		
Hooper							
Limestone							
Sadie Peak							
Marmot Mtn.							
McQuillan							
Moriarty					▲		
P Mtn							
Tangle						■	
Whymper			■				
Strathcona							
Castlecrag					▲		
Drinkwater						■	
Flower Ridge							

	2010	2011	2012	2013	2014	2015	2016
Frink							
Greig Ridge							
Henshaw				■			
Marble Meadows							
Morrison Spire						■	
Phillips							
Sunrise							
Tibetan							
Washington							
Schoen Lake							
Seth							
Clayoquot Plateau							
Steamboat							

Appendix 2. Results of Threats Calculator Teleconference, September 21, 2016. Originally published in Vancouver Island Marmot Recovery Team (2017) and included with permission.

THREATS ASSESSMENT WORKSHEET			
Species or Ecosystem Scientific Name	Vancouver Island Marmot		
Element ID	33	**Elcode**	
Date (Ctrl + ";" for today's date):	9/21/2016		
Assessor(s):	Dave Fraser (R.P. Bio.,Unit Head, Species Conservation Science, BC Ministry of Environment) Sean Pendergast (R.P. Bio., Senior Wildlife Biologist, BC Ministry of Forests, Lands, and Natural Resource Operations) Cheyney Jackson (M.Sc., Field Coordinator, Marmot Recovery Foundation) Malcolm McAdie (D.V.M., Wildlife Veterinarian, Marmot Recovery Foundation) Adam Taylor (Executive Director, Marmot Recovery Foundation) Sally Leigh-Spencer (R.P.Bio., Ecologic Consulting) Elizabeth Gillis (Ph.D., Professor, Vancouver Island University)		
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	Overall Threat Impact Calculation Help:		Level 1 Threat Impact Counts	
	Threat Impact		high range	low range
	A	Very High	0	0
	B	High	1	0
	C	Medium	1	1
	D	Low	1	2
Calculated Overall Threat Impact:			High	Medium
Assigned Overall Threat Impact:			**BC = High - Medium**	
		Overall Threat Comments	Average age six years; under best case scenarios, with adequate management, threats such as predation, climate change, and road mortality can potentially be mitigated. Captive-breeding to supplement the population has effectively mitigated the impacts of predation over the past 10 years and resulted in an increase in the marmot population. Modelling by Jackson *et al*. (2015) suggests that continued captive breeding could have a similar result over the next 10 years. Some of the impacts of climate change can be mitigated (e.g., manual removal of tree ingrowth or supplemental feeding in case of drought) and may result in a net benefit to the species.	

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development		Not a Threat	Small (1-10%)	Neutral or Potential Benefit	Moderate (Possibly in the short term, < 10 yrs/3 gen)	
1.1	Housing & urban areas						There may be some additional housing/cabin development at Mount Washington, but any new development will likely occur at elevations lower than where the marmots are.
1.2	Commercial & industrial areas						
1.3	Tourism & recreation areas		Not a Threat	Small (1-10%)	Neutral or Potential Benefit	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Expansion of the trail network for skiing and mountain biking is expected to occur at Mount Washington within the next few years. There may be some short term negative impact of trail creation, but this will be negated by a longer term net benefit to marmots because the cleared areas, if maintained, will increase the amount and quality of habitat for marmots.
2	Agriculture & aquaculture						
2.1	Annual & perennial non-timber crops						
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching						
2.4	Marine & freshwater aquaculture						
3	Energy production & mining						
3.1	Oil & gas drilling						

Threat		Impact (calculated)	Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
3.2	Mining & quarrying					There are inactive mines near some marmot colonies (Mount Washington, Mount McQuillan). If these mines are ever re-opened, the threat posed to marmots by mining will have to be reassessed. There is an active mine at Buttle Lake, in the vicinity of marmot habitat, but it is operating at a minimum level and because of its location in a provincial park, it is closely monitored and unlikely to expand.
3.3	Renewable energy					At the time of the threat assessment, there were no run of the river or wind projects that were likely to affect marmots.
4	Transportation & service corridors	Negligible	Small (1-10%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	
4.1	Roads & railroads	Negligible	Small (1-10%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Food addition in the spring has been used to draw marmots away from roads at Mount Washington . There have been no known instances of marmots being killed by vehicles on roads to date. Marmots may be more at risk of threats from roads when dispersing, but dispersers are usually young males whose death will have less of an effect on population numbers than if dispersers were females.
4.2	Utility & service lines					Utility and service lines, if maintained tree free, may benefit marmots through creation and maintenance of habitat.
4.3	Shipping lanes					
4.4	Flight paths					
5	Biological resource use	Unknown	Small (1-10%)	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	
5.1	Hunting & collecting terrestrial animals	Not a Threat	Restricted - Small (1-30%)	Neutral or Potential Benefit	High (Continuing)	Marmots may be killed through poaching or collected from the wild to augment the captive breeding population. Poaching could have a small negative impact, but will likely be rare. There has been one case reported (but not verified) of a marmot on Green Mountain being shot. In contrast, over a 10 year time scale, collection of marmots for captive breeding will have a positive effect on the population because captive born marmots are released back into the wild. Over the last 20 years (1997 - 2016) 61 marmots have been collected for the breeding program and 490 marmots from the captive population have been released into the wild; approximately eight marmots released for every marmot collected).

Threat		Impact (calculated)	Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.2	Gathering terrestrial plants					
5.3	Logging & wood harvesting	Unknown	Small (1-10%)	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	At several colonies, marmot hibernacula have been associated with forested habitat, so the loss of trees may have a negative effect. Other than at Mount Washington, however, the trees are at high elevation and small, and therefore unlikely to be logged. Some of the land on Mt. Washington is privately owned, and marmots have occupied hibernacula on this forested land for over a decade. The landowner has wanted to harvest this area for approximately 15 years but has chosen not to because of the potential impact on the marmots. If logging occurred in this part of Mount Washington, it is unknown how the marmots that use the hibernacula within this forested habitat would respond. They may die overwinter (a small negative impact), they may move to another site, or may not be affected. If there is a negative effect, it is unknown if it would affect only the marmots currently residing there or if marmots in the future would also use these hibernacula and be negatively impacted. Recently logged habitats may also negatively affect the population if dispersers settle and create colonies in these habitats. Recently logged areas may provide "good" marmot habitat temporarily, but it is ephemeral habitat that decreases in quality as trees start to regrow and close in.
5.4	Fishing & harvesting aquatic resources					
6	Human intrusions & disturbance	Not a Threat	Pervasive (71-100%)	Neutral or Potential Benefit	High (Continuing)	
6.1	Recreational activities	Not a Threat	Large (31-70%)	Neutral or Potential Benefit	High (Continuing)	Marmots live on ski hills, near mountain biking trails, and in alpine areas popular for hiking. These activities appear to have few negative effects, although there is always a small risk that a marmot could be hit by a mountain bike or a dog accompanying a hiker could kill a marmot or transmit a disease. Humans recreating near marmot colonies probably benefit marmots because marmot predators may avoid areas of high human use.
6.2	War, civil unrest & military exercises					

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6.3	Work & other activities		Not a Threat	Pervasive (71-100%)	Neutral or Potential Benefit	High (Continuing)	There are two groups of workers that would frequent marmot colonies - marmot researchers and employees of the Mount Washington ski resort. The presence of workers near marmot colonies probably benefits marmots because marmot predators may avoid areas of high human use.
7	Natural system modifications	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)	
7.1	Fire & fire suppression		Unknown	Small (1-10%)	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Mount Washington is at lower elevation and the marmots live in open areas (ski trails) surrounded by trees. At this site, fire suppression could have a negative impact by preventing the benefits of fire (e.g., forest clearing).
7.2	Dams & water management/use	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	A new water reservoir is planned for Mount Washington. With sufficient funding, any marmots that would be directly affected by the flooding of burrows could be moved. In the past, two marmots drowned (along with several other species) in a reservoir because the lining material was slippery and the marmots could not climb out. Steps have been taken to ensure this cannot happen again. The reservoir could be designed and constructed to ensure that marmots could escape if they entered the reservoir, thus, reducing the risk greatly. Buttle Lake's water level is controlled by the Strathcona Dam (water levels raised 8.5 m in 1958 with construction of dam). Buttle Lake may be a barrier to dispersal or force marmots to disperse further to get around the lake; marmots have been document to disperse around the western end of the lake.
7.3	Other ecosystem modifications	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)	Dispersing marmots have in the past created colonies in clearcuts, as early successional forests mimic alpine meadows. Post-logging succession decreases the quality of that habitat and with the eventual ingress of trees it can also create a greater risk of predation. Clearcuts are ephemeral habitat that decreases in quality for marmots as trees start to regrow. Colonies in these areas are extirpated 5 - 10 years after establishment.
8	Invasive & other problematic species & genes	BD	High - Low	Pervasive (71-100%)	Serious - Slight (1-70%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.1	Invasive non-native/alien species/diseases		Unknown	Unknown	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Loss of genetic diversity associated with a small population size may increase the susceptibility of marmots to disease. There are numerous potential ways in which non-native diseases could enter the marmot population, but the risk and potential impact is unknown. If a disease causes high mortality, it will probably have a large negative effect in a small area and then die out. If it causes morbidity but low mortality, it might become chronic in the population. Potential sources of non-native disease could be via other species of rodents (e.g. Yellow-bellied Marmot, Hoary Marmot) that are accidently transported to Vancouver Island via vehicles and goods, via domestic pets, such as dogs, that accompany humans into marmot habitat, or via humans recreating in and around marmot colonies. Another potential source of non-native disease is via the release of captive born marmots; both facilities where captive marmots are held are multispecies facilities, where marmots could come in contact with other mammal species, including rodents. They are also transported by air, and may encounter other mammal species in cargo holds. The disease risk associated with release of captive born marmots into the wild is minimized through quarantine at Mount Washington and health checks prior to release.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.2	Problematic native species/diseases	BD	High - Low	Pervasive (71-100%)	Serious - Slight (1-70%)	High (Continuing)	Predation by native predators (Cougar. Grey Wolf, Golden Eagle) accounts for the vast majority of mortality in marmots. Predation on marmots will be greatly affected by the number of predators in the area of colonies; the number of predators will be variable and may depend on the number and behaviour of the primary prey of the predators (deer, elk, rabbits). In addition, if marmots are in a "predator pit" because of inverse density dependence at low population density, when marmots are below a threshold density, predators will regulate marmots. In a predator pit situation, above the threshold marmot density, predators will not regulate the population of marmots. The effect of predators is most likely reduced in areas of high human use because Cougar and Grey Wolf tend to avoid these areas. Predation can also be mitigated by management activities, including legal hunting and trapping. Population viability analysis has shown that marmot populations can persist long term if they experience relatively low mortality, as observed in the past. Indeed, the marmot population in the wild has increased in the recent past.
8.3	Introduced genetic material		Negligible	Negligible (<1%)	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	There have been at least six recorded instances of Yellow-bellied Marmot reaching Vancouver Island via accidental transport in vehicles and goods (lumber). It is unlikely that the two species would hybridize even if in the same habitat. It is unlikely, but not impossible, that a Hoary Marmot could reach Vancouver Island through similar means. It might be possible for Hoary and Vancouver Island Marmot to hybridize as they are sister species and there is evidence of past genetic introgression of Hoary Marmot DNA in Vancouver Island Marmot.
8.4	Problematic species/diseases of unknown origin		Unknown	Unknown	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Loss of genetic diversity associated with a small population size may increase the susceptibility of marmots to disease, but risk of exposure is unknown.
8.5	Viral/prion-induced diseases		Unknown	Unknown	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Loss of genetic diversity associated with a small population size may increase the susceptibility of marmots to disease, but risk of exposure is unknown.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.6	Diseases of unknown cause		Unknown	Unknown	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Loss of genetic diversity associated with a small population size may increase the susceptibility of marmots to disease, but risk of exposure is unknown.
9	Pollution						Marmots have been tested for chemical residues/toxins in the past. Evidence of exposure was found, but any toxins found were at very low levels and do not raise any concerns.
9.1	Domestic & urban waste water						
9.2	Industrial & military effluents						Mount Washington does not use herbicides but there is a contaminated old mine site at Mount Washington.
9.3	Agricultural & forestry effluents						Herbicides used by forestry companies are specific, mostly on roadside brush or out of control plantations. The typical herbicide is glyphosate with spot application through backpack sprayer. The forestry company was consulted, and it was concluded that herbicide use in marmot habitat is not an issue.
9.4	Garbage & solid waste						
9.5	Air-borne pollutants						
9.6	Excess energy						
10	Geological events		Unknown	Pervasive (71-100%)	Unknown	Unknown	
10.1	Volcanoes						
10.2	Earthquakes/tsunamis		Unknown	Pervasive (71-100%)	Unknown	Unknown	Vancouver Island Marmot lives on Vancouver Island, which is a geologically active earthquake zone. It is conceivable that an earthquake could occur over the next 10 years, but the strength and probability of a significant earthquake cannot be predicted, and if it occurred, its impact on marmots is unknown.
10.3	Avalanches/landslides		Negligible	Pervasive (71-100%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Marmots live at high elevation on steep mountains, and therefore live in areas of high avalanche risk. Although there could be negative effects of avalanches on some marmots, avalanches also remove trees, thereby improving habitat. If avalanche frequency decreases (because of climate change) forest ingrowth may occur resulting in a reduction in marmot habitat. Such impacts could be mitigated through forest management (e.g., selective tree clearing in old avalanche chutes).
11	Climate change & severe weather	D	Low	Large - Restricted (11-70%)	Slight (1-10%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.1	Habitat shifting & alteration	D	Low	Large - Restricted (11-70%)	Slight (1-10%)	High (Continuing)	Negative effects of habitat alteration, in the form of tree growth, have occurred and are expected to be large on a 20-year time scale (i.e., increased forest cover decreases the quality of habitat by increasing risk of predation). The negative effects have and can be mitigated through removal of these trees. If mitigation continues, there is the potential for a positive effect through enhancement and creation of habitat. In the absence of mitigation, tree growth will have a negative effect. On a much longer time scale, habitat could be altered by climate change. Thelin *et al.* (2018) predicted that the amount of suitable habitat for marmots on Vancouver Island will decrease as a function of climate change.
11.2	Droughts		Unknown	Pervasive (71-100%)	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Following a drought in the summer of 2015, overwinter survival for marmots in some colonies was abnormally low, indicating drought may negatively impact the marmot population. Drought can decrease forage quality and availability thereby reducing reproductive output and pup growth rate. The potential severity is unknown and could be variable because marmots may change their behaviour and many have the option to use a nearby slope or area where conditions are not as dry.
11.3	Temperature extremes		Unknown	Pervasive (71-100%)	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	High temperatures may reduce the time marmots forage because they become inactive during the hottest time of the day. Temperature extremes may also reduce snow pack persistence and whether winter precipitation is snow or rain, both of which may affect the metabolic cost of hibernation and overwinter survival. The negative impact will be minimized for some marmots because they live in areas where there is a spectrum of habitat available and they may move to more favorable habitat. At this point, the impact cannot be predicted.
11.4	Storms & flooding		Unknown	Small (1-10%)	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	There is anecdotal evidence that spring flooding of hibernaculums can cause mortality of marmots, but if it occurs it is most likely to have a very local effect for only a few individuals.
11.5	Other impacts						

Classification of Threats adopted from IUCN-CMP, Salafsky *et al*. (2008).